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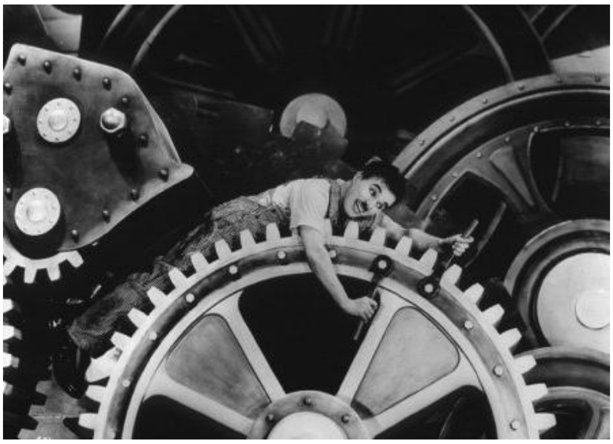

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WP2 – DELIVERABLE

Composite Indicators measuring structural change, to monitor the progress towards a more knowledge-intensive economy in Europe

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Executive summary

This report is the deliverable of the second work package (WP2) of the feasibility study entitled ERA MONITORING and financed by DG RTD. The objective of this work package is to explore the possibility to develop a composite indicator of structural change towards a more knowledge-intensive economy in Europe, coherently with the orientations of the EU 2020 strategy and the Innovation Union initiative.

The theoretical framework and the indicators required for this feasibility study are those proposed in the Expert Group Report *Indicators for Structural Change*[1], which aimed to identify measurements of the various key dimensions of innovation, of the impact of innovation on the economy and of the capacity of the economy to change in order to foster innovation.

Of the three domains of structural change proposed by the expert group (*enablers*, *compositional* and *Schumpeterian*) we decided to focus on the indicators of *compositional* structural change for two reasons. First, because the computation of *Schumpeterian* indicators would be too expensive given the available resources; second, because *enablers* represent framework conditions for structural change rather than an objective quantification of structural change itself.

The indicators of *compositional* structural change address modifications in the composition of technologies, research and development, output, exports, foreign direct investments, towards an economy that is becoming more and more knowledge-intensive. Changes may affect the linkages among sectors and technologies, and influence the changes of the international advantages of countries.

Ten *compositional* indicators have been identified by the expert group and have been organized into five pillars: *Research & Development* (government R&D expenditures and value added in the total economy by R&D as a service sector), *Skills* (employment of tertiary graduates in knowledge-intensive activities), *Sectoral specialization* (specialization in knowledge intensive sectors), *International specialization* (revealed technological and competitive advantage) and *Internationalization* (inward and outward foreign direct investments). Each pillar contains exactly two *compositional* indicators. The five pillars have also been aggregated to a single composite indicator of structural change to provide an overall measure of country progress in this area.

The countries included in this analysis are all EU Member States, EFTA Countries Norway and Switzerland, Candidate country Turkey, and Europe's main competitors, namely the United States, Japan and China.

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[1] Malerba F., Salter M., Saltelli A. 'Expert Group on the Measurement of Innovation: Indicators for Structural change', Brussels, 29 September 2011.

The ten indicators of *compositional* structural change, the related five pillars, and the overall composite indicator have been calculated for four time points: 1995, 2000, 2005 and 2009. The number of missing values was the highest for the first time point, year 1995, still composite indicators could be calculated for all time points. This allowed the team to compare the performances of the countries across a time span of approximately 15 years with time steps of approximately 5 years. The most reliable data available for the period 2000 to 2009 makes it appropriate to show changes in the structure of the economy.

At the international level, the composite indicator reveals leadership of the United States in the *compositional* structural change, followed by Japan, the EU-27 and China, in this order.

In terms of evolution over the period 2000-2009, China has undergone the highest ratio of change toward a high-tech, knowledge-intensive economy (with 39% increase in the overall composite score), while both Japan and the EU-27 showed a more modest change (16 and 12%, respectively). United States succeeded in maintaining its leading position with only 8% increase in the composite score. Considering the 34 Countries we observed, all of them have shown positive change over this period.

As far as the five pillars are concerned, the EU-27 underperforms in most of the pillars compared to its competitors, is on average in the *skills* pillar, but performs best in the *Internationalization* pillar considering the most recent time point.

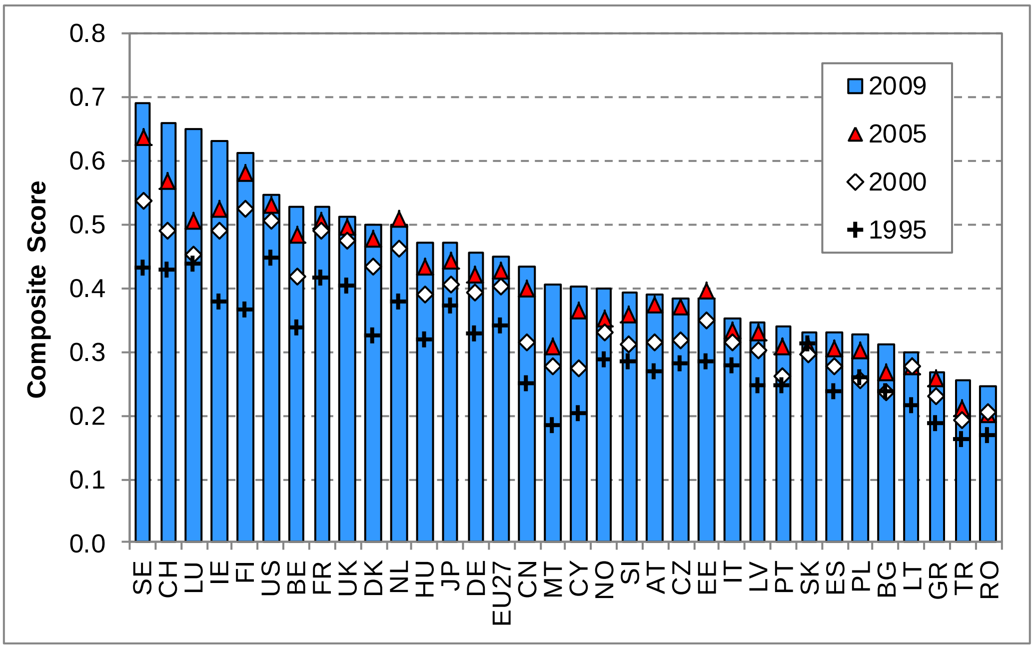

Figure 1 Composite Indicator of Compositional Structural Change,

At the European level, the composite scores show that Sweden, Switzerland, Luxembourg, Ireland and Finland have the most high-tech, knowledge-intensive economic structure. A heterogeneous group of Member States composed by Belgium, France, the United Kingdom, Denmark, the Netherlands, Hungary and Germany show evidence of a developed knowledge-intensive economy with above-average composite scores. Countries that still need to make progress are Romania, Turkey, Greece, Lithuania and Bulgaria.

Considering the evolution over time, 8 European countries have made the greatest improvement toward a knowledge intensive economy by achieving over 29% change in the level of the composite score over the period 2000 to 2009. These best performers were Cyprus, Malta, Luxemburg, Switzerland, Bulgaria, Turkey, Portugal and Ireland. At the same time, the United Kingdom, Netherlands, France, Lithuania, Estonia, Italy and Slovakia) have made less progress (between 8 and 12%).

At the pillar level, the changes in the scores over time show a heterogeneous picture. In an international comparison, the EU-27 achieved the greatest increase in the *internationalization* pillar (28% level change over the period 2000-2009). The 14% and 18% change in the *skills* and *sectoral specialization* pillars (respectively) of the EU-27 were, however, less than that of its Asian competitors. Nevertheless, the worst performer at the pillar level was the US, with negative changes in the *R&D*, *international specialization* and *internationalization* pillars. China achieved high growth in all pillars, except for *internationalization.*

Within Europe, the best performers in *R&D* pillar were Estonia, Cyprus and Portugal, with Slovakia, Latvia, Luxemburg and France showing decline. Almost all countries except for Lithuania achieved growth in the *skills* pillar, with the best performers being Romania, Turkey and Poland. Considering *sectoral specialization*, Sweden, Luxemburg, Finland and Slovakia achieved over 60% increase, while Estonia, Romania, Lithuania and Cyprus saw 6% decline. Smaller countries achieved the largest growth in the *international specialization* in high-tech pillar, including Malta, Cyprus and Slovenia, while a large number of larger countries have seen decline in this dimension over 2000-2009. The *internationalization* pillar (FDI in and outflows) saw triple-digit growth for Luxemburg, Cyprus, Belgium and Ireland, and very modest growth (below 16%) for France, Greece and Denmark.

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1. Introduction and objectives

The EU2020 strategy contains a blueprint for transforming Europe into an 'Innovation Union' by 2020. The Innovation Union flagship initiative (October 6th, 2010) commits the EU to boosting investment in research and making Europe an attractive place to develop innovative products. Consequently, national governments will have to reform their innovation systems to boost cooperation between industry and universities, ensure a modernization of framework conditions for enterprises, and a number of other measures to enhance cross-border cooperation and to embrace joint programming. All these innovation aspects need to be carefully monitored by policy-makers in the European institutions and Member states.

This feasibility study, entitled 'ERA monitoring', focuses on monitoring the progress of Europe towards the completion of the European Research Area (ERA), towards the structural change of national and super-national innovation systems and towards the modernization of higher-education institutions.

The project addresses the feasibility to develop three conceptual frameworks (organised in three work packages – WPs) and the potential to further aggregate the underlying components into composite indicators to measure:

> WP 1:
> progress in the construction and integration of a European Research Area (ERA), to monitor the overall performance of the Science and Technology system.
>
> WP 2:
> structural change, to monitor the increase towards a more knowledge-intensive economy in Europe coherently with the orientations of the EU 2020 strategy and the Innovation Union initiative.
>
> WP 3:
> research excellence in Europe, meaning the effects of European and National policies on the modernization of research institutions, the vitality of the research environment and the quality of research outputs in both basic and applied research.

The present deliverable represents the outcome of WP 2 of the project.

The objective of this work-package is to test the feasibility to develop a composite indicator to measure the structural change of the economy of all EU Member States, most EFTA countries, Candidate countries and the main international competitors of the European Union (United States, Japan and China). The study intends to cover these countries for as many years as possible, depending on data availability.

In this WP – as well as in WP1 and WP3, the steps mentioned in the OECD/JRC Handbook[2] have been followed:

step1. Development of a theoretical framework for the measurement of structural change. The framework has been derived from that identified by the report entitled *Indicators for Structural Change*, co- authored by Franco Malerba, Ammon Salter and Andrea Saltelli, and discussed at the plenary meeting of the expert group on the measurement of innovation held in Brussels on September 29th, 2011.

The construction of the theoretical framework has implied the following phases:

a. Use of the framework identified by the report *Indicators for Structural Change*;
b. Collection of data sources at country level, and for as many years as possible, for all EU27 Member States, most EFTA countries, Candidate countries, and the main international competitors of the European Union (United States, Japan and China).

step2. Multivariate statistical tools have been used to assess the suitability of the data set and to ease the understanding of the implications of the methodological choices, e.g., weighting and aggregation, during the construction phase of the composite indicator. Statistical analysis has been used for imputing missing data, detecting outliers, and to suggest suitable transformations of indicators due to skewness or kurtosis. Correlation analysis and principal component analysis has been used to check whether the structure of the underlying data is consistent with the identified conceptual framework and therefore is sufficient and appropriate to describe the phenomenon. Note that principal component analysis has not been used as a weighting method.

step3. Construction of the composite indicator. The composite indicator has been constructed by considering both linear and geometric aggregations of the five pillars with equal weights. Each pillar, composed of two indicators, has been calculated by taking their arithmetic average.

step4. Sensitivity analysis has been conducted to appreciate the relative importance of the five pillars on the overall composite and of each pillar with respect to its indicators. The results confirm that the composite structure is quite balanced in its components.

[2] Nardo M., Saisana M., Saltelli A., Tarantola S., Hoffman A., Giovannini E., (2008) *Handbook on constructing composite indicators: methodology and user guide*. OECD publishing. http://www.oecdbookshop.org/oecd/display.asp?CID=&LANG=en&SF1=DI&ST1=5KZN79PVDJ5J

2. Theoretical framework: indicators of structural change

The 'Indicators for Structural Change' report by the Expert Group on the Measurement of Innovation[3] identified three types of indicators related to structural change: enablers, compositional and Schumpeterian. *Enablers* refer to the conditions in a country which could support or hinder variety and novelty creation by firms, such as the business environment, attitudes to science and technology or the availability of venture capital. *Compositional structural change* indicators measure changes in the actual sectoral composition of the economy in terms of research and development (R&D), skills output, exports, technologies and foreign direct investment (FDI). *Schumpeterian structural change* indicators refer to the micro level, primarily to the dynamics of innovation and entrepreneurship at the firm level.

This feasibility study focuses on the *compositional* indicators only for a variety of reasons. As the Expert Group report states, the measurement of this set of indicators is more "mature and available" than others. Schumpeterian indicators in particular are considered to be weak mainly due to lack of systematic data coverage, and data could not be collected given the cost and time constraints of this study.[4] There are also issues of overlap: some of the indicators of the Innovation Union Scoreboard can be seen, to a large extent, as structural change *enablers* indicators. Moreover, the qualitative differences between the three types of structural change indicators are so great that they would make it meaningless to combine them into a single composite indicator. In sum, and also taking into account the time constraints of this study, a "conservative" selection of compositional indicators allows the most thorough investigation for the calculation of a composite indicator of structural change.

Compositional indicators of structural change can be grouped into five dimensions, highlighting different dimensions of structural change. The *R&D dimension* measures both the investment into new technological solutions or diversity creation in general, as well as the relative share of dedicated R&D service providers in the economy. The *Skills dimension* measures changing skills and occupations in terms of professionals in an economy and also the share of persons employed in knowledge intensive activities, where in general at least one third of the persons employed in general have a university degree. *Sectoral specialization* captures the relative share of the knowledge economy within a country in terms of production (both in manufacturing and service sectors), while the *international specialization* dimension captures the share of knowledge economy through technological (patents) and export specialization. Finally, the *internationalization* dimension refers to the changing international competitiveness of a country in terms of attracting and diffusing

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[3] Malerba F., Salter M., Saltelli A. 'Expert Group on the Measurement of Innovation: Indicators for Structural change', Brussels, 29 September 2011. Hereafter referred to as the 'Export Group Report'.

[4] Of the Schumpeterian indicators identified by the Expert Group, S1 (share of new firms in top 100 in each country), S2 (new large R&D spenders in a country) require in-depth data collection from business registers at the country-level; S3 (net entry rates into knowledge-intensive sectors) and S4 (share of young firms that innovate) require an increase in the coverage of Eurostat data; while S6 (share of population aspiring high-growth entrepreneurship) needs data quality improvement in the Global Entrepreneurship Monitoring survey results. No proxies could be identified as a replacement for any of these indicators.

foreign direct investment (FDI). The Expert Group report identified the following list of compositional structural change indicators:

a) R&D
   C1. Change in the level of Government non-defence R&D expenditures
   C2. Share of R&D services in the economy
b) Skills
   C3. Changing skills and occupation
   C4. Change in the share of employment in knowledge-intensive activities (KiAs, see box 1)
c) Sectoral specialization
   C5. Change in countries' sectoral specialization
   C6. Change in countries' international productive specialization in knowledge-intensive sectors
   C7. Change in countries' international productive specialization in knowledge-intensive sectors (relative index)
   C8. Input-output change
d) International specialization
   C9. Change of countries' international technological specialization (RTA)
   C10. Change in export specialization in medium-high tech and high-tech products (RCA)
   C11. Change in international value chain
e) Internationalization
   C12. Increase in internationalization (change in FDI stocks)

In this study we use the same five dimensions and the same list of indicators, with the exception of four: C6, C7, C8 and C11. Indicator C6 and C7 are removed in order to avoid polarization and duplication: C5 is virtually the same as C7, the only difference being that it is not divided by a constant ratio; C6 is a global distribution indicator, with highly skewed distribution towards large countries. Indicators C8 and C11 were not included because of no data currently available.[5] Moreover, indicators C3 and C12 in fact refer to two indicators each. Even after these considerations, a framework of 5 dimensions proposed by the Expert Group could be applied, with two indicators available for each of the pillars (except for sectoral specialization), as shown in the next section.

In sum, a composite indicator constructed in this way measures the importance of high-tech, knowledge-based production and export activities within the structure of an economy. It is more than a measure of sectoral specialization in selected manufacturing and service activities, because it looks at financial (R&D investment and FDI stocks) and technological dimensions, and to some extent, also at the competitiveness of an economy (in terms of

[5] Data availability in the medium term requires the computation of Leontief multipliers for all knowledge-intensive activities using input-output tables in the case of C8; in the case of C11 it depends on the release of a new OECD database "Bilateral trade by end-use", due early 2012.

export specialization). The main strength of a composite should lie in its ability to show trends over time, indicating structural change towards a high-tech, knowledge-based economy. Therefore, a composite is less meaningful when computed for only a few recent years, and requires comparable data for at least a decade-long time period.

3. Indicators definition and data availability

The subsequent section provides a detailed overview of the meaning, definition, data source, specific notes and quality profile of the indicators used. For some indicators, an alternative definition (proxy) had to be used in order to increase data availability and comparability. In what follows, both the unused original indicator and the chosen proxy are described.

<u>A note on the interpretation of 'change' in this study</u>: All the indicators proposed by the Expert Group intend to measure *change* in a specific dimension (e.g. "C1: Change in the level of Government non-defence R&D expenditures"). For the purpose of this report, we consider 'change' as level changes in aggregate composite scores, and individual variables measure levels at one given time point (Thus, C1 becomes "Level of Government non-defence R&D expenditures").

<u>R&D indicators</u>

Indicator code: C1 and C1-Alt

<u>Name and definition proposed by the Expert Group</u>:

C1: The level of government non-defense R&D expenditures

<u>Definition</u>: Total government budget appropriations or outlays for non-defense R&D as a share of total government expenditures

<u>Meaning</u>: The indicator measures investment into civilian science and technology

<u>Data sources</u>:

- Eurostat Total GBAORD by NABS 1992 and NABS2007 socio-economic objectives [gba_nabsfin92] and [gba_nabsfin07])
- Eurostat Total GBAORD as a % of total general government expenditure [gba_nabste]
- OECD Government budget appropriations or outlays for RD dataset (GBAORD)
- National sources (i.e. for external comparison with China, India)

<u>Shortcomings identified</u>:

- Missing GBAORD data for time point 1995 for all countries and limited coverage for remaining years; defense R&D budget not available for IL, BG, HU, SK, RU for some or all years. **Due to these limitations, the alternative indicator C1(Alt) was used.**

<u>Name and definition of indicator actually used in this study</u>:

C1(Alt): Total R&D expenditure as a share of GDP (%)

Data sources:

- EUROSTAT Total intramural R&D expenditure (GERD) by sectors of performance
- Chinese National Bureau of Statistics, Science and Technology Yearbooks, various editions

Notes and quality profile:

- Time period: 1995 to 2009 time points are considered,
- Countries: EU27 countries, EU27 total, TR, CH, NO, JP,US, IS, CN
- Limited/partial coverage data: MT (1995-1999 not available); HR (1995-2001)
- Missing data: MK, IL, LI, BR, RU, IN, ZA.

Indicator code: C2

Name and definition proposed by the Expert Group:

C2: The share of R&D services in the economy

Definition: the share of sector NACE Rev 1.1 code K73 in the total economy, in terms of value added

Meaning: This indicator measures the relative size of research and development as a service sector in the total economy

Data sources:

- Eurostat Structural Business Statistics;
- OECD STAN;
- EUKLEMS

Notes and quality profile:

- Time period: 1995 to 2009 time points are considered,
- Countries: most of EU27 countries (CY missing), EU27 total, NO, JP, US, IS (partial), IL (partial), KR,
- Limited/partial coverage data: BG, MT, RO, CH, IS, IL, US
- Missing data: CY, HR, MK, TR, LI, BR, RU, IN, CN, ZA

Skills indicators

Indicator code: C3A&B and C3-Alt

Name and definition proposed by the Expert Group:

C3: Skills and occupation [of labour force]

Definition: C3A: Share of university graduates employed in manufacturing sectors (based on occupation); C3B: Share of university graduates employed in services sectors (based on occupation)

Meaning: measures the share of highly skilled employees in total work force (representing the basis of the knowledge economy)

Data sources:

- Eurostat Annual data on HRST and sub-groups, employed, by sector of economic activity and gender [hrst_st_nsecsex]
- (Annual data on HRST and sub-groups, employed, by sector of economic activity)

Shortcomings identified:

- Poor data coverage for both manufacturing and services sector HRST employment for some EU27 for years before 2000; no data available for US, JP, CN and BRICS.
- The distinction of HRST in manufacturing and services sectors is only meaningful for descriptive statistics, but information loss occurs when aggregating for a composite indicator.
- **To overcome these limitations, the alternative indicator C3(Alt) was used.**

Name and definition of indicator actually used in this study:

C3(Alt): Share of Human Resources in Science and Technology (HRST) as a share of active population (15-74) (%)

Data sources:

- EUROSTAT Annual data on HRST and sub-groups, by gender and age [hrst_st_ncat]
- OECD Tertiary education attainment of population aged 25-64 (%) [series used for imputing US, JP, CN and KR]

Notes and quality profile:

- Time period: 1995 (partial coverage), 2000, 2005, 2009 time points are considered,
- Countries: most of EU27 countries, HR, MK, TR, CH, IS, NO,
- Limited/partial coverage data: KR, JP, US and CN not available in the EUROSTAT source; the OECD source is not completely compatible (difference in age cohort; time coverage (1997-2009); and only 2000 in case of CN.
- Missing data: LI, IL, BR, RU, IN, ZA;
- Human Resources in Science and Technology (HRST) follows an occupation-based definition; includes those who have successfully completed a tertiary level education or are not formally qualified as above but employed in a S&T occupation where the above qualifications are normally required,
- Since the data originates from European Union Labour Force Survey, the coverage of this indicator is limited to EU member states, candidates and EFTA countries. Figures for US, JP, CN and KR were imputed using a regression-based method with the help of the above-mentioned OECD data due to the high correlation between the two series (0.78-0.84)

Indicator code: C4

Name and definition proposed by the Expert Group:

C4: The share of employment in knowledge-intensive activities (KiAs)

Indicator definition: persons [15-74] employed in knowledge-intensive activities (KiAs) as a percentage of total employment. [In sectors with at least 33% tertiary graduates]

Meaning: measures the relative share of knowledge-intensive sectors in total employment

Data sources:

- EUROSTAT Annual data on employment in knowledge-intensive activities at the national level, by gender (until 2008, NACE Rev.1.1) (htec_kia_emp)
- EUROSTAT Annual data on employment in knowledge-intensive activities at the national level, by gender (from 2008, NACE Rev.2) (htec_kia_emp2)
- EUKLEMS www.euklems.net
- OECD STAN

Relevant sectors:

- NACE Rev. 1.1 codes: 23, 24, 30, 32, 33, 62, 65, 66, 67, 72, 73, 74, 75, 80, 85, 91, 92, 99
- NACE Rev. 2 codes: 09, 19, 21, 26, 51, 58-66, 69-75, 78-79, 84-86, 90-91, 94, 99

Notes and quality profile:

A combination of different sources was necessary due to limited coverage of the Eurostat KIA employment database. The ESTAT dataset based on NACE Rev 1.1 was used for the EU27 countries, with coverage until 2008. We decided not to combine this with the NACE Rev 2 data because of a break in series due to definition change. 1995 figures were extrapolated using the growth ratio in a similar, but incomplete KIA series computed from OECD STAN and EU KLEMS employment figures in the relevant sectors. As the ESTAT dataset does not cover non-EU countries, time series for JP, KR and the US were calculated by summing employment in relevant sectors using OECD and EU KLEMS sources (and eventually extrapolating for missing time points within the respective source sector time series). The resulting aggregate is comparable to ESTAT data. Missing years for the EU27 total were extrapolated using a linear regression function. The Chinese figure for the year 2000 was imputed based on comparative tertiary education attainment figures in population aged 25-64 (source: OECD *Education at a Glance 2011*). The following quality profile refers to the computed dataset:

- Time period: 1995 to 2009 time points are considered,
- Countries: EU27 countries, EU27 total, CH, IS, NO, KR, JP, US, IS, KR,
- Limited/partial coverage
    - Missing or incomplete data: HR, MK, TR, HR (up to 2001); TR and MK (up to 2005); CN (2000 available only)
    - Missing data: LI, IL, BR, RU, IN, ZA,

Sectoral specialization indicators

Box 1 Specialization in the knowledge economy: conceptual issues

Specialization in *knowledge-intensive activities* is a recurrent feature of the compositional variables, albeit in various dimensions: employment, production, technology and exports. The Expert Group Report has already addressed the problems of measuring specialization in knowledge-intensive sectors, emphasizing that “a recent definition change can be a source of confusion.” (p.12)

The “*old definition*” of Eurostat and OECD classifies manufacturing sectors as *high-tech* according to technology intensity (R&D expenditure/value added), based on NACE 3-digit level classification. In addition to this, Eurostat created a classification also for service sectors known as *knowledge-intensive services* (KIS), based on the share of tertiary educated persons (at NACE 2-digit level). Out of these, three were further flagged as knowledge-intensive *high-tech* services. Data according to this combined high-tech manufacturing and knowledge-intensive services classifications are available from Eurostat for both NACE Rev. 1.1 and NACE Rev. 2 definitions (this latter became the standard as of 2008).

In contrast, *a new definition* was created in order to have a uniform classification criterion for both manufacturing and services sectors, when DG-RTD introduced the concept of *Knowledge-intensive Activities* (KiAs). NACE 2-digit sectors were flagged as knowledge intensive if the share of tertiary educated persons employed was more than 33% of total employment within that activity. A subset of KiAs was identified as KiA Business industries (KIABI).

Ideally, specialization from all aspects should be measured according to the new KiA definition. However, currently, Eurostat only provides aggregated statistics on *employment* in knowledge-intensive activities at the national level. Other structural variables, such as value added, gross output, or number of enterprises are unavailable at the moment. Manual calculation using a combination of international datasets (Eurostat Structural Business Statistics, OECD STAN, EU KLEMS, UNIDO Industrial Statistics) is also not possible due to missing data on many of the KiA service sectors (including KIABIs).

As an alternative measurement of the size of the knowledge economy, the Export Group Report suggested using aggregations according to the old (hi-tech for manufacturing, knowledge-intensive for services) definition. Accordingly, this study uses the KiA definition for employment (indicator C4), and the alternative definitions for all other variables. As show in ANNEX-III (table from Expert Group Report), the difference between the two definitions are substantial for service sectors, thus lower levels of correlation between the two sets of variables should not be surprizing.

Indicator code: C5 and C5-Alt

Name and definition proposed by the Expert Group:

C5: Countries' sectoral specialization

Definition: The share of value added in knowledge-intensive manufacturing and service sectors (KiAs) within the total value added in a country. (Sector selection is based on the high proportion of tertiary educated employees (at least 33%) – Eurostat "knowledge intensive activities"; see relevant sectors below)

Meaning: Measures transition towards a knowledge-based economy in terms of value added in manufacturing and service sectors

Data sources:

- EUROSTAT Economic statistics on high-tech industries and Knowledge Intensive Services at the national level (1995-2007, NACE Rev.1.1/Rev.2) (htec_eco_sbs/2/);
- EUROSTAT European Business - selected indicators for all activities (NACE divisions) (ebd_all) [Structural Business Statistics (SBS)]
- EUKLEMS www.euklems.net

- OECD *STAN Database for Structural Analysis* UNIDO or National statistical bureaus for non-EU / non-OECD countries. Note that data for services at 2/3 digit levels are rarely available
- Eurostat *Economic statistics on high-tech industries and Knowledge Intensive Services at the national level (1995-2007, NACE Rev.1.1) (htec_eco_sbs)* and *Economic statistics on high-tech industries and Knowledge Intensive Services at the national level (from 2008, NACE Rev.2) (htec_eco_sbs2)*
- UNIDO IndStat
- National statistical offices (i.e. China, India, Turkey)

Shortcomings identified:

- Eurostat has so far not published value added figures aggregated according to the KIA classification. Manual computation using Eurostat SBS, OECD STAN or EU KLEMS data is not possible due to the large share of missing time series for service sectors (See Box 1).
- **To overcome these limitations, the alternative indicator C5-Alt was used.**

Name and definition of indicator actually used in this study:

C5-Alt: The share of value added in high-tech manufacturing and service sectors within the total value added in a country. [R&D intensity-based definition; Relevant sectors for alternative definition applied: See Box 1 and ANNEX-III for further description. [High-technology manufacturing (NACE Rev 1.1. DG24.4, DL30, DL32, DL33, DM35.3) and knowledge-intensive high-technology services (I64, K72 and K73).]

Data sources: (Same as above)

Notes and quality profile:

- See description on compilation of dataset in ANNEX-I.
- Time period: 1995 to 2009 time points,
- Countries: EU27 countries, EU27 total, CH, NO, IS, KR, JP, US,
- Limited/partial coverage: TR, CN
- Missing data: HR, MK, IS, LI, IL, BR, RU, IN, ZA,

Indicator code: C6 and C6-Alt

Name and definition proposed by the Expert Group:

C6: Countries' international productive specialization in knowledge-intensive sectors

Definition: value added in knowledge-intensive manufacturing and service sectors (KiAs) in country j over the total value added in knowledge-intensive industries in the world.

Meaning: measures countries' specialization in selected sectors in terms of world shares.

Alternative definition:

C6-Alt: value added in high-tech manufacturing and knowledge-intensive service sectors country *j* over the total value added in knowledge-intensive industries in the world. [R&D intensity-based definition]

Notes:

- Eurostat has so far not published value added figures aggregated according to Indicator C6 and C6-Alt can be derived from indicator C5 by calculating a country's share in total world's value added in the selected sectors. Therefore, the above-mentioned notes and quality profile applies here as well.
- C6 and C6-Alt are very much size-dependent

Indicator code: C7 and C7-Alt

Name and definition proposed by the Expert Group:

C7: Countries' international productive specialization in knowledge-intensive sectors: relative index ["share of shares"]

Definition: share of value added in knowledge-intensive sectors (KiAs) in country *j* over share of value added in knowledge-intensive sectors (KiAs) in the world.

Meaning: measures countries' specialization in selected sectors in terms of world shares compared to the global share of the selected sectors.

Alternative definition:

The share of value added in high-tech sectors in country *j* over share of value added in high-tech sectors in the world [R&D intensity-based definition; see relevant sectors below]

$$\frac{VA_j^{KIA}}{VA_j^{TOTAL}} \Bigg/ \frac{\sum_j VA_j^{KIA}}{\sum_j VA_j^{TOTAL}}$$

(Values over 1 indicate specialization in knowledge-intensive industries.)

Indicator C7 and C7-Alt is also a derivative of indicator C5 (calculated by dividing C5 /-Alt/ with a constant share of the world's value added in the selected sectors). The above-mentioned notes and quality profile applies here as well. Since the two are proportional, they are redundant.

International specialization

Indicator code: C9

Name and definition proposed by the Expert Group:

C9. Countries' international technological specialization
(Revealed Technological Advantages - RTA)

Definition: the share of selected technology classes in a country's patents (PCT) relative to the share of the selected technological classes in total world patents.

Meaning: the indicators measures revealed technological advantages (RTA) in selected fields

Data sources:

- Eurostat, OECD Patent Statistics: (Patent applications to the EPO by priority year at the national level by sector of economic activity (NACE class derived through concordance with IPC) [pat_ep_nnac])

Relevant sectors:

- KIA manufacturing industries: NACE Rev.1.1 23, 24, 30, 32, 33

Notes and quality profile:

- Time period: 1995 to 2009 time points are considered,
- Countries: EU27 countries, EU27 total, HR, TR, CH, IS, LI, NO, IL, BR, RU, CN, ZA,CN, KR, JP, US, HR, IS, LI, IL, BR, RU, ZA, KR,
- Limited/partial coverage data: CY: 1995 missing
- Missing data: MK, IN,
- Good coverage, but for countries with very few patents, percentages are not comparable across countries. Eurostat advises users to read data for small countries with caution.

Indicator code: C10 and C10-Alt

Name and definition proposed by the Expert Group:

C10. Export specialization in medium-high tech and high-tech products

(Revealed Competitive Advantages – RCA)

Definition: Exports of medium-high and high-technology products as a share of total exports over the world market share of high-tech exports

Meaning: the indicator measures changes in countries' specialization in exporting medium-high and high-tech products;

Data sources:

- UN COMTRADE; Innovation Union Scoreboard 2010

Shortcomings identified:

- There is no agreed definition of a 'medium-tech exports' classification, Eurostat only provides data for high-tech exports. The calculations used in the Innovation Union Scoreboard are based on a non-official concordance tables. **For the sake of clarity in definition, the alternative C10-Alt was used.**

Alternative definition used: Share of high technology products in total exports over world market share of high-tech exports

- EUROSTAT: Exports of high technology products as a share of total exports (1995-2006, SITC Rev. 3) [htec_si_exp]; (from 2007, SITC Rev. 4) [htec_si_exp4]
- EUROSTAT World market share of high-tech trade (intra EU-trade excluded) by high-tech group of products - EU and 20 main partners (1995-2006, SITC Rev. 3) [htec_trd_weu]; (from 2007, SITC Rev. 4) [htec_trd_weu4]
- EUROSTAT World market share of high-tech trade (intra EU-trade included) by high-tech group of products - EU Member States and 20 main partners (1995-2006, SITC Rev. 3) [htec_trd_wms]; (from 2007, SITC Rev. 4) [htec_trd_wms4]
- UN COMTRADE

Notes and quality profile:

- Time period: 1995 to 2009 time points are considered,
- Countries: EU27 countries, EU27 total, TR, CH, NO, BR, CN, IN, JP, KR, RU, US

- Limited/partial coverage data: none,
- Missing data: HR, MK, IS, LI, IL, BR, RU, IN, ZA, KR
- Note that export specialization does not necessarily refer to local production; this indicator should be seen together with indicators on specialization in high-tech production (value-added based),
- High-tech sectors recalculated according to Eurostat definition table (SITC Rev.3) in order to increase coverage for non-member states. The following sectors were considered (SITC Rev.3):

  87411, 75113, 75997, 76381, 76383, 7722, 77261, 77318, 77625, 77627, 7763, 7764, 7768, 89879, 5413, 5415, 5416, 5421, 5422, 774, 871, 87211, 88111, 88121, 88411, 88419, 7787, 77884, 71489, 71499, 7187, 72847, 7311, 73131, 73135, 73142, 73144, 73151, 73153, 73161, 73163, 73164, 73165, 73312, 73314, 73316, 7359, 73733, 73735, 52222, 52223, 52229, 52269, 525, 531, 57433, 591, 77862, 77863, 77864, 77865, 77867, 77868, 89961, 89963, 89966, 89967, 87412, 87413, 87414, 8743, 8744, 8745, 8746, 8747, 8749, 7641, 7642, 7643, 7648, 76491, 76492, 75131, 75132, 75134, 7521, 7522, 7523, 7526, 7527, 7921, 7922, 7923, 7924, 7925, 79291, 79293.

Internationalization

Indicator code: C12A and C12B

Name and definition proposed by the Expert Group:

C12A&B: Internationalization (Levels of inward and outward FDI)

Definition:

- C12A: Cumulative inward FDI stock as a share of GDP
- C12B: Cumulative outward FDI stock as a share of GDP

Meaning: measure active internationalization by increasing inward and outward FDI stocks

Data source:

- UNCTAD UnctadStat 'Inward and outward foreign direct investment stock, annual'

Notes on data availability (both inward and outward):

- Time period: 1995 to 2009 time points are considered,
- Countries: EU27 countries, EU27 total, TR, CH, NO, HR, MK, IS, IL, BR, CN, IN, KR, JP, RU, US, ZA
- Missing data: none
- FDI stock is the value of the share of their capital and reserves (including retained profits) attributable to the parent enterprise, plus the net indebtedness of affiliates to the parent enterprises.

To summarize, the indicators retained for further analysis are presented below:

Table 1 Indicators retained for further investigation

Indicator	Definition
R&D Indicators	
C1-Alt:	Total R&D expenditure as a share of GDP (%)
C2:	The share of R&D services in the economy (the share of sector NACE Rev 1.1 code K73 in the total economy, in terms of value added)
Skills Indicators	
C3-Alt:	Share of Human Resources in Science and Technology (HRST) as a share of active population (15-74) (%)
C4:	Share of persons [15-74] employed in knowledge-intensive activities (KiAs) as a percentage of total employment.
Sectoral Specialization Indicator	
C5-Alt:	The share of value added in high-tech manufacturing and service sectors within the total value added in a country
International Specialization Indicators	
C9:	Relative specialization in holding PCT patents in selected technology classes (Revealed Technological Advantage – RTA)
C10-Alt:	Relative specialization in the export of medium-high tech and high-tech products (Revealed Competitive Advantage – RCA)
Internationalization Indicators	
C12A:	Cumulative inward FDI stock as a share of GDP
C12B:	Cumulative outward FDI stock as a share of GDP

4. Data treatment (univariate analysis)

Given that structural change in an economy occurs not year-on-year but over decades, longer time series data is required to measure trends. When collecting data for the indicators, a guiding principle was to have systematically collected data for as many years as possible – which was either readily available or could be calculated by the JRC team within the time horizon (i.e. the specialization indicators). Despite the considerable efforts made to gather data some gaps still remained. Nevertheless, it was possible to find a relatively high coverage for four reference time points: year 1995, year 2000, year 2005 and the most recent year, which is either 2008 or 2009, depending on the indicator. In the following we will indicate these four reference time points as 1995, 2000, 2005 and 2009.

Selection of countries

The aim of the report is to assess the feasibility of constructing composite indicators for the EU27 Member States and major competitors. We have investigated the possibility to include all EU candidate countries, EFTA and BRICS countries. Ideally, 10-15% of missing data is considered as a threshold for including a country or an indicator, but this "rule of thumb" had to be relaxed for the sake of a more comprehensive assessment. Countries with the lowest data availability (below 60% on average), including Croatia, FYRO Macedonia, Liechtenstein, Israel, Brazil, Russia, India and South Africa, as well as Iceland (with no data on *skills*) had to be excluded from further analysis. The countries that remained in the sample were thus the EU27 Member States, Switzerland, Norway, China, Japan and the United States. Table 2 and Table 3 show the overall data availability by country and by indicator for the four reference time points.

Table 2 Data availability (in %) by country for the 4 reference time points: countries excluded from the analysis (with availability below 60%) are shown in red.

Group		Country	*1995*	*2000*	*2005*	*2009*
EU-27	AT	Austria	*100*	*100*	*100*	*100*
	BE	Belgium	*100*	*100*	*100*	*100*
	BG	Bulgaria	*78*	*100*	*100*	*100*
	CY	Cyprus	*78*	*89*	*89*	*89*
	CZ	Czech Republic	*100*	*100*	*100*	*100*
	DE	Germany	*100*	*100*	*100*	*100*
	DK	Denmark	*100*	*100*	*100*	*100*
	EE	Estonia	*100*	*100*	*100*	*100*
	GR	Greece	*100*	*100*	*100*	*100*
	ES	Spain	*100*	*100*	*100*	*100*
	FI	Finland	*100*	*100*	*100*	*100*
	FR	France	*100*	*100*	*100*	*100*
	HU	Hungary	*100*	*100*	*100*	*100*
	IE	Ireland	*100*	*100*	*100*	*100*
	IT	Italy	*100*	*100*	*100*	*100*
	LI	Lithuania	*100*	*100*	*100*	*100*
	LU	Luxembourg	*67*	*100*	*100*	*100*
	LV	Latvia	*100*	*100*	*100*	*100*
	MT	Malta	*78*	*89*	*89*	*89*
	NL	Netherlands	*100*	*100*	*100*	*100*
	PL	Poland	*100*	*100*	*100*	*100*
	PT	Portugal	*100*	*100*	*100*	*100*
	RO	Romania	*78*	*100*	*100*	*100*
	SE	Sweden	*100*	*100*	*100*	*89*
	SI	Slovenia	*100*	*100*	*100*	*100*
	SK	Slovakia	*100*	*100*	*100*	*100*
	UK	United Kingdom	*100*	*100*	*100*	*100*
AGGREGATED EU-27			*100*	*100*	*100*	*100*
Candidate Countries	HR	Croatia	*56*	*56*	*78*	*78*
	MK	FYRO Macedonia	*44*	*44*	*56*	*56*
	TR	Turkey	*67*	*78*	*89*	*89*
EFTA	CH	Switzerland	*89*	*100*	*100*	*100*
	NL	Norway	*100*	*100*	*100*	*100*
	IS	Iceland	*78*	*89*	*89*	*89*
	LI	Liechtenstein	*22*	*22*	*22*	*22*
ERA	IL	Israel	*44*	*44*	*56*	*56*
BRICS	BR	Brazil	*56*	*56*	*56*	*56*
	RU	Russia	*44*	*44*	*44*	*44*
	IN	India	*44*	*56*	*56*	*56*
	CN	China	*67*	*89*	*67*	*67*
	ZA	South Africa	*44*	*44*	*44*	*44*
Others	JP	Japan	*100*	*100*	*100*	*100*
	US	United States	*100*	*100*	*100*	*89*

Table 3 Overall data availability (in %) by indicator for four time points

Indicators / short description		1995	2000	2005	2009
C1-Alt:	Total R&D expenditure	*79.6*	*81.8*	*84.1*	*84.1*
C2:	Value added in R&D services sector	*70.5*	*75.0*	*77.3*	*72.7*
C3-Alt:	Human resources in science and technology	*84.1*	*86.4*	*84.1*	*84.1*
C4:	Employment in KIAs	*72.7*	*79.6*	*84.1*	*84.1*
C5-Alt:	Domestic sectoral specialisation	*72.7*	*81.8*	*81.8*	*81.8*
C9:	Technological specialization in high-tech	*95.5*	*97.7*	*97.7*	*97.7*
C10-Alt:	Export specialization in high-tech	*97.7*	*100.0*	*100.0*	*100.0*
C12A:	Inward FDI stock	*95.5*	*97.7*	*97.7*	*97.7*
C12B:	Outward FDI stock	*95.5*	*97.7*	*97.7*	*97.7*

Key descriptive statistics of indicators

The basic descriptive statistics of the nine structural change indicators for the countries and time points selected based on the considerations discussed above are presented in Table 4. The percentages of missing values were thus calculated for the set of countries considered in the analysis, after exclusion of those with high rate of missing values. Indicator C2 has the highest share of missing values for all time points, and 1995 is the time point with the lowest coverage. The rest of the indicators and years have not more than 3% missing values (most of the cases due to no data available for China, Turkey, Cyprus and Malta).

Table 4 Descriptive statistics of structural change indicators used, 4 time points

Name of indicator	**C1-Alt**				**C2**				**C3-Alt**			
Description	Total R&D / GDP				Value added in R&D services sector (NACE Rev 1.1 K73)				HRST			
Source	EUROSTAT, China (N.B.S.)				EUROSTAT				EUROSTAT + OECD			
Reference year	1995	2000	2005	2009	1995	2000	2005	2008	1995	2000	2005	2008
% of missing values:	*3*	*0*	*0*	*0*	*12*	*9*	*9*	*15*	*3*	*0*	*3*	*3*
mean value	1.36	1.43	1.51	1.72	0.004	0.004	0.004	0.003	29.26	32.26	35.91	38.87
standard deviation (unbiased)	0.84	0.95	0.94	0.99	0.004	0.002	0.003	0.002	8.45	9.03	8.22	8.53
Maximum value	3.26	3.86	3.56	3.96	0.014	0.010	0.013	0.008	44.73	47.81	48.73	53.60
Minimum value	0.20	0.24	0.40	0.46	0.000	0.000	0.000	0.000	10.18	13.38	16.58	19.20

Name of indicator	**C4**				**C5-Alt**				**C9**			
Description	KIA Employment				Domestic sectoral specialisation				Revealed technological advantage			
Source	EUROSTAT, EUKLEMS, OECD				EUROSTAT, EUKLEMS, OECD, UNIDO, national sources				EUROSTAT, OECD			
Reference year	1995	2000	2005	2008	1995	2000	2005	2008	1995	2000	2005	2008
% of missing values:	*12*	*3*	*3*	*3*	*12*	*3*	*3*	*3*	*3*	*0*	*0*	*0*
mean value	35.77	36.79	38.87	39.54	5.14	6.97	8.22	8.37	0.92	0.93	0.94	1.00
standard deviation (unbiased)	7.78	8.68	9.34	9.49	1.36	2.67	3.41	3.79	0.23	0.15	0.17	0.15
Maximum value	49.76	51.00	57.60	60.00	8.98	15.18	16.01	18.47	1.47	1.23	1.30	1.29
Minimum value	25.78	16.80	20.10	21.20	2.57	3.27	2.59	2.70	0.20	0.62	0.55	0.76

Name of indicator	**C10-Alt**				**C12A**				**C12B**			
Description	High-tech export specialisation				Inward FDI				Outward FDI			
Source	EUROSTAT				UNCTAD				UNCTAD			
Reference year	1995	2000	2005	2009	1995	2000	2005	2009	1995	2000	2005	2009
% of missing values:	*3*	*0*	*0*	*0*	*3*	*0*	*0*	*0*	*3*	*0*	*0*	*0*
mean value	0.62	0.72	0.77	0.73	13.60	35.45	41.40	60.84	10.25	25.11	31.21	50.19
standard deviation (unbiased)	0.67	0.65	0.60	0.46	12.35	32.35	26.07	44.28	12.24	28.38	33.89	56.33
Maximum value	3.31	3.22	2.70	1.79	65.89	154.88	115.91	192.08	44.75	91.98	126.96	243.00
Minimum value	0.05	0.08	0.06	0.08	0.00	1.08	2.22	3.95	0.02	0.26	0.21	0.87

Imputation of Missing data

The imputation of missing data was carried out at two levels. Firstly, a basic quality improvement of the original data series, which were used for the numerator and denominator of the various indicators, was done by imputing values for missing years by linear trend extrapolation and interpolation country by country. This was only used if a linear trend could be identified, with no breaks or fluctuations prevalent in the data source. Such a quality-improvement-at-the-source exercise was crucial in order to minimize the number of missing values for ratio-type indicators where a numerator or denominator was not available for one of the selected benchmark years (note also the imputation made for indicator C3 – see definition of C3). The data availability percentages shown in Table 2 reflect the obtained result.

At the next level, missing values for the indicators at one of the four time points were imputed in the following way (in the order shown below):

- Linear extrapolation over the 4 time points, if a linear trend was identified (in the case of indicator C9 CY 1995); alternatively, replication of the value of the nearest time point of the same country, in the cases where the extrapolation resulted in a logically erroneous value (C2 US 2009; C4 BG and RO 1995, TR 1995 and 2000; C5-Alt CY and RO 1995; C10-Alt LU and US 2000).
- Linear regression-based imputation in case a country had no observations at any time point for a given indicator. Values were imputed by applying a linear regression between the given indicator and another indicator showing the highest correlation. (This was used in the case of indicator C5 for TR and CN). In case one observation was available for a country for a given indicator, the known year of the same indicator was used to predict the values for the missing years (used in the case of indicators C3-Alt and C4 for CN, for time points 1995, 2005 and 2009).
- Finally, in case either matching values were also missing in the closely correlating series, or would have resulted in logically incorrect values, the average across the other available indicators for the same country was used on the normalized values. (This was the case of CY C2 all time points; LU C12 A&B 1995, MT C1-Alt, C5-Alt and C10-Alt for all time points; CH C2 1995; and TR and CN C2 all time points.)

Outlier detection

Outliers in data series can polarize composite scores and bias rankings. An excessive skewness or kurtosis values in indicators at a given time point indicate the existence of outliers.[6] As a treatment, extreme values were replaced by the n^{th} highest value of the sorted considered data, for the *n* which provided a skewness and kurtosis value within the desired range. Two indicators were flagged as problematic: C10-Alt and C12A. In the case of export

[6] The threshold criteria for flagging series to contain outliers was the combination of absolute skewness value of 2 and a kurtosis greater than 3.5, as suggested in Groeneveld, R. A. and G. Meeden, 1984, "Measuring skewness and kurtosis". *The Statistician* 33: 391-99.

specialization indicator C10-Alt, the values for Malta were removed and replaced by the average; in the case of C12A, the 1995 values of Belgium, Ireland and Luxemburg were replaced with the value of Spain and the 2000 values for Belgium, Ireland, Luxemburg, Netherlands were replaced by the next highest value of Denmark.

5. Multivariate statistical analysis

Multivariate analysis was carried out on the 10 indicators normalized using the min-max method.

Correlation analysis

The correlation analysis carried out for the normalized data for all time points showed that all the correlations, significant at least at 5%, were positive. Of "indicator pairs" grouped together in the Expert Group report, the strongest, significant correlation was observed between skills indicators C3 and C4 (correlation coefficient 0.75) and between FDI indicators C12A and C12B (0.71), when considering all years together. This value was lower for the R&D indicators C1 and C2 (0.39) and for international specialization indicators C9 and C10 (0.26), but still positive and significant (Table 64).

We also observed significant, strong, positive correlation between the skills and outward FDI indicators C4 and C12B (0.73), the R&D and skills indicators C1 and C4, and C1 and C3 (both 0.67). The high-tech domestic and export specialization indicators C5 and C10 also show positive correlation (0.62). The lowest correlation coefficients with other indicators were observed for the technological specialization indicator C9.

Table 5 Correlation coefficients and significance levels, all time points combined

	C1-Alt	C2	C3-Alt	C4	C5-Alt	C9	C10-Alt	C12A	C12B
C1-Alt	1								
C2	**0.385*** **	1							
C3-Alt	0.671***	0.170*	1						
C4	0.668***	0.345***	**0.748*** **	1					
C5-Alt	0.577***	0.305***	0.480***	0.494***	1				
C9	0.085	0.005	0.170*	-0.023	0.284***	1			
C10-Alt	0.500***	0.193*	0.427***	0.414***	0.621***	**0.257** **	1		
C12A	0.029	0.029	0.386***	0.440***	0.277**	0.063	0.161	1	
C12B	0.455***	0.251**	0.582***	0.725***	0.378***	-0.041	0.309***	0.711***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The correlation coefficients change little when the four time points are considered separately. Some exceptions were observed in case of indicator pairs C9–C10, where correlation coefficients fluctuated between 0.14 (at time point 1995) and 0.38 (time point 2000). In the case of internationalization indicators C12A–C12B, the high coefficient for time point 1995 0.85 dropped to 0.4 by the time point 2000, before returning to 0.57 in 2005 and 0.73 in 2009. This fluctuation can be explained by the rapid growth in inward FDI, driven by the forces of globalization. We also observed some fluctuation in the case of domestic and export specialization indicators C5 and C10, where the coefficients for time point 2000 were significantly higher than for 2009 (0.86 and 0.52, respectively).

Principle Component Analysis

Classical principal component analysis (PCA) is usually done at pillar level to highlight whether all the indicators within the pillar capture a given latent dimension. In this study, given that a pillar consists of only two indicators, the correlation coefficient is sufficient for this aim. We also conducted PCA over all indicators (see Box 2) but no clear components emerged from the dataset (neither when considering all time points together, nor when separately). Three latent components were considered with eigenvalues greater than 1, which together explain 74% of variance in the data. The first component correlates significantly with indicators C1, C3, C4, C5, C10, C12A and C12B (with loading values of 0.39, 0.2, 0.41, 0.43, 0.37, 0.32, 0.25 and 0.38, respectively). However, the second component has both positive (C5, C9 and C10 with 0.30, 0.44 and 0.36 loading coefficients respectively) and negative (C12A and C12B with -0.53 and -0.42 values respectively) signs of significant correlation. Similarly, in the third component, we found significant negative signs in the case of indicators C1, C2, C4, and positive for indicators C9 and C12A. Although with different coefficients, similar results were found when the four time points were considered separately.

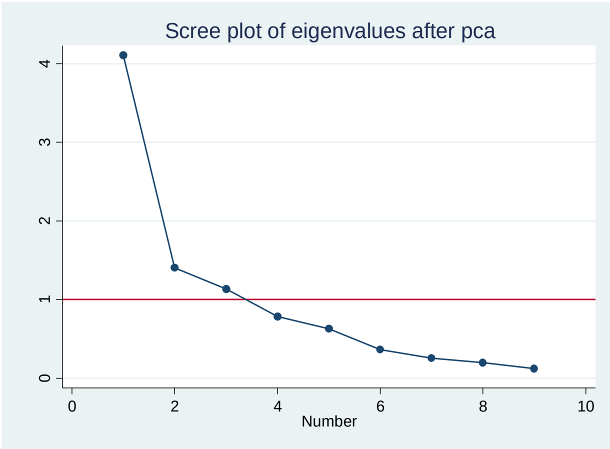
In conclusion, no meaning linked with aspects of structural change could be found for these latent components. As a consequence, we could not use the PCA results for statistically defining pillars of indicators. Instead, we opted to use the conceptual grouping of indicator pairs suggested by the Expert Group report.

Box 2 Results of the Principal Component Analysis, all times points combined

```
Principal components/correlation                  Number of obs    =       136
                                                  Number of comp.  =         9
                                                  Trace            =         9
    Rotation: (unrotated = principal)             Rho              =    1.0000
    --------------------------------------------------------------------------
       Component |   Eigenvalue   Difference         Proportion   Cumulative
    -------------+------------------------------------------------------------
           Comp1 |      4.10695      2.70142             0.4563       0.4563
           Comp2 |      1.40553      .273205             0.1562       0.6125
           Comp3 |      1.13233      .348675             0.1258       0.7383
           Comp4 |      .783653      .153773             0.0871       0.8254
           Comp5 |       .62988      .265583             0.0700       0.8954
           Comp6 |      .364297      .108749             0.0405       0.9358
           Comp7 |      .255548     .0584367             0.0284       0.9642
           Comp8 |      .197111     .0724143             0.0219       0.9861
           Comp9 |      .124697            .             0.0139       1.0000
    --------------------------------------------------------------------------
```

PCA for the indicators: correlation coefficients between the indicators and the PCA components

	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7	Comp8	Comp9
C1-Alt	0.387	0.243	-0.303	-0.282	0.194	-0.112	0.471	0.340	0.482
C2	0.207	0.166	-0.522	0.758	0.101	0.143	-0.199	0.108	-0.022
C3-Alt	0.407	-0.047	0.048	-0.342	0.390	0.046	-0.590	0.353	-0.293
C4	0.430	-0.174	-0.161	-0.128	0.158	0.064	-0.103	-0.816	0.193
C5-Alt	0.365	0.302	0.125	0.098	-0.374	-0.746	-0.071	-0.082	-0.205
C9	0.090	0.442	0.629	0.288	0.509	0.106	0.174	-0.129	0.010
C10-Alt	0.320	0.359	0.157	-0.115	-0.595	0.609	-0.070	0.026	0.024
C12a	0.256	-0.533	0.412	0.304	-0.150	-0.064	-0.154	0.231	0.534
C12b	0.384	-0.426	0.044	0.115	-0.008	0.135	0.562	0.071	-0.563



6. Computation of the composite indicator and results

Based on the findings of the Expert Group and on data availability, a composite indicator on *Compositional Structural Change* was built as depicted in Figure 2. The *R&D pillar* is composed of C1-Alt and C2, the *Skills pillar* associates C3-Alt and C4. The *Sectoral specialization pillar* only includes indicator C5-Alt, because C6-Alt could not be used due to its highly skewed distribution[7] and because C7-Alt did not differ from C5-Alt, save for a constant denominator (see discussion in the indicators definition section). The *international specialization pillar* associates C9 and C10-Alt, and finally the *internationalization pillar* associates C12A and C12B. Each of them is computed by taking the arithmetic average of the 2 indicators composing it, except for the *Sectoral specialization* pillar, which is represented by indicator C5-Alt suitably normalized.

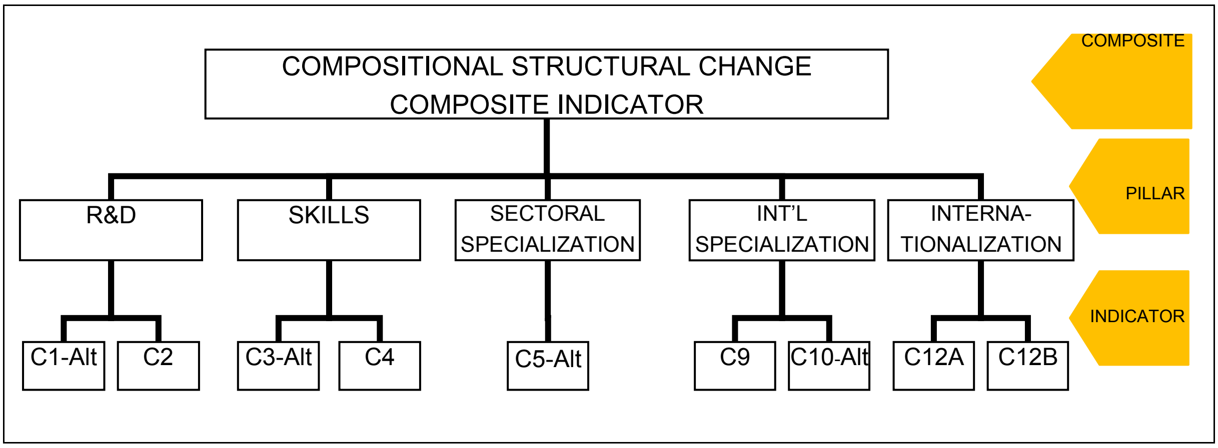


Figure 2 The composite indicator and its dimensions

Eventually, the composite indicators were calculated by (a) taking the arithmetic and (b) the geometric average of the 5 pillar scores of each country for the time points 1995, 2000, 2005 and 2009. In this study all pillars were considered with an equal weight in both aggregation methods, as the Expert Group report offered no conceptual justification to do otherwise.

[7] Although there are logarithmic normalization techniques to reduce skewness, but since they come at a cost of significant loss of information, we decided not to use indicator C6-Alt.

There was also no justification to use different weights for countries at different level of development, since, in fact, all indicators used are associated with structural change toward a high-tech, knowledge-based economy.[8] In any case, the actual effective weight of the individual indicators will be revisited in the section on sensitivity analysis below.

The **resulting composite indicators** for each country are shown in Figure 3 for the four time points, aggregated with the geometric average method. Figure 4 plots the composite scores by countries at time point 2009 on the map, shaded according to quintiles. At the European level, the five leaders are Sweden (with a score of 0.69), Switzerland (0.66), Luxembourg (0.65), Ireland (0.63) and Finland (0.61). With a distance, they are followed by a North Western European “belt” with Belgium, France, the United Kingdom, the Netherlands and Germany, joined by Hungary (the composite scores for these countries range from 0.46 to 0.53). On the other extreme, “peripheral” position is clearly associated with the lowest composite scores. This group includes Eastern (Romania, Lithuania, Bulgaria, Poland and Slovakia) and Southern Member States (Greece, Spain) as well as Turkey, with scores ranges of 0.25-0.33.
In a global comparison, the United States are in a clear leading position with a score of 0.55, followed neck and neck by Japan (0.47), the EU-27 (0.45) and China (0.44). Replacing the geometric with the **arithmetic average** method allows countries to compensate their below-average performance in one pillar by above-average performance in another. While the US leadership position remains stable, both Japan and China are ranked higher in an international comparison when using the arithmetic average method. (Their composite scores, in turn, are: US: 0.61, JP: 0.54, CN: 0.52 and EU-27: 0.46). Nevertheless, the use of the geometric average across pillars gives countries an incentive to increase performance in their weakest indicators.

[8] The EU Regional Competitiveness Index 2010 (Annoni, P. and Kozovska, K., 2010, “EU Regional Competitiveness Index”, *JRC Scientific and Technical Report*), for instance, applies different weights for its very heterogeneous set of regions based on their level of development, arguing that there are intrinsically different factors driving their competitiveness. A similar arrangement does not hold in this case, because structural change is understood here with a clear orientation toward specialization in knowledge-based, high-tech sectors in almost all of the indicators.

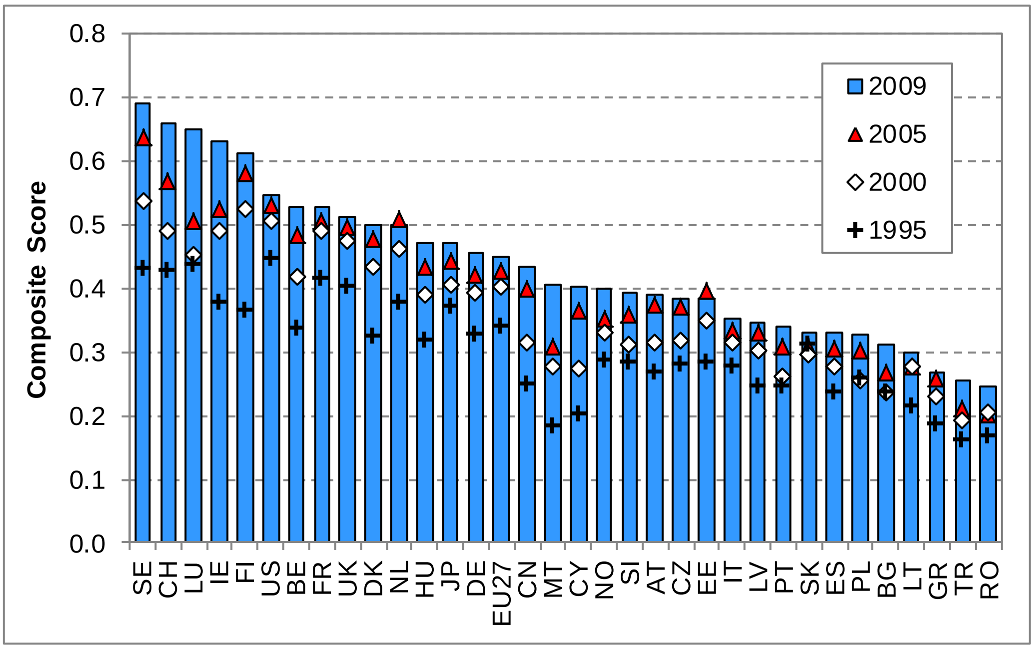


Figure 3: Composite Indicator of Compositional Structural Change, geometric average method of aggregation (2000-2009)

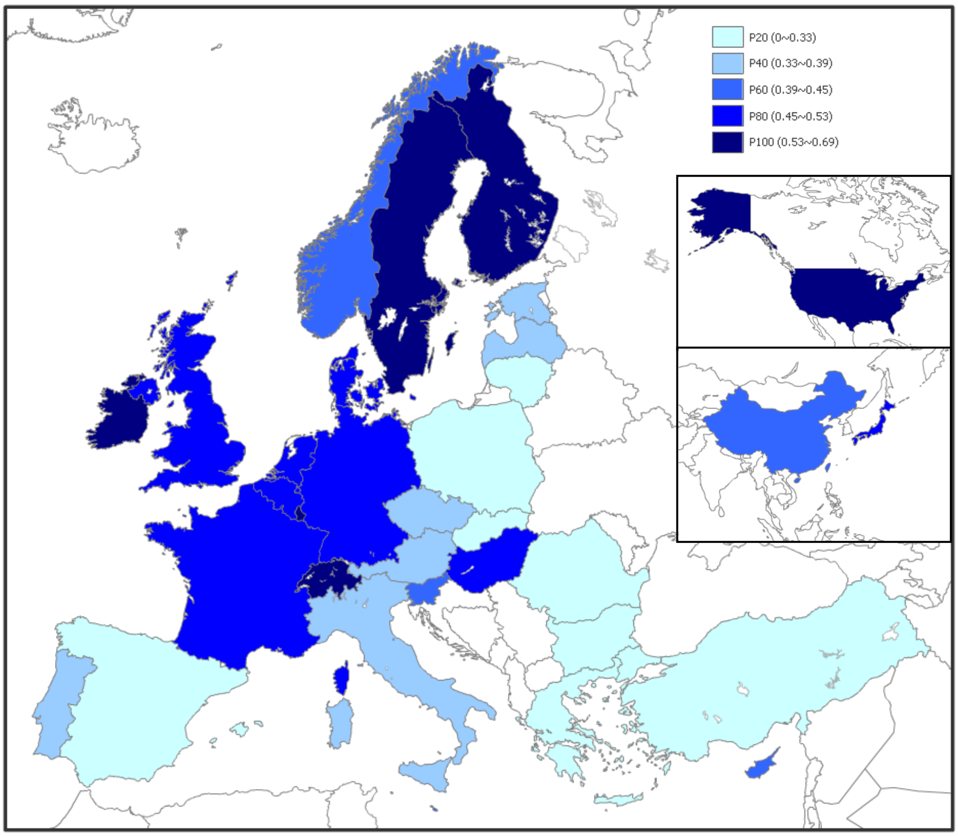


Figure 4: Map of Composite Indicator of Compositional Structural Change, geometric average method of aggregation (2009)

What is behind the best performance in 2009?

The only common feature of the best performing countries is their high scores in the skills pillar; the other pillars showing strong performance vary. Sweden's outstanding composite score is due to its high *R&D*, *sectoral specialization*, and *skills* pillars scores (despite the slightly below-average performance in the *international specialization* pillar). Switzerland stands out in *skills*, *International specialization* and *internationalization*; Luxemburg in the *skills*, *internationalization* and *sectoral specialization* pillars (but has below-average scores in *international specialization*). Ireland's strength lies in the *sectoral-* and *international specialization* as well as in the *skills* pillars, with a relatively weak score in *R&D*. Finland excels in *sectoral specialization*, *skills* and *R&D*, but has a below average score in internationalization.

In a global comparison, the US performs best in the *skills*, *sectoral*, *international specialization* pillars, but has a below average score in *internationalization*. In the case of Japan, good scores are the *R&D, sectoral specialization* as well as *international specialization* pillars, but a very poor *internationalization* score pulls back the country to the middle ranks. Interestingly, this profile is also valid for China.

What is behind the worst performance? A pillar by pillar analysis shows that Turkey performs especially poorly in the *internationalization*, *R&D* and *sectoral specialization* pillars. The weak position of Romania is due to the *sectoral*, *internationalization* and *skills* pillars, notwithstanding its above-average performance in the *international specialization* pillar (this is an interesting example of an enclave-like export sector). Greece scores low in the *internationalization*, *R&D*, and *sectoral specialization* pillars, with below-average performance for the rest of the pillars, similarly to Lithuania and Bulgaria.

Evolution of the indicators over time

Composite indicators of structural change are more meaningful when level changes are considered over time rather than comparing actual values at a given time point across countries. Such trends are shown in Figure 5 and Figure 6, using year 2000 as a reference time point.[9] Clearly, all countries have made progress toward a high-tech, knowledge-intensive economy, but the pace of change varies between 8 (the United Kingdom) and 48% (Cyprus). The results of the most recent financial crisis are not yet visible as the economic structure is slow to change.

Figure 5 plots the level and growth rates of structural change in a quadrangle.[10] Compared to the EU27 weighted average, most of the countries show a growth rate above this average. However, the larger economies maintain a growth rate in line with that of the EU27. The

[9] 2000 was chosen as a benchmark because it already offers an almost a decade's overview, but also because data coverage for the time point 1995 was lower. Nevertheless, the trends are clearly visible in the following figures.

[10] We thank Professor Rémi Barré for proposing to add this graph, which is also used in the Innovation Union Scoreboard.

countries below the EU27 score are catching up, with the exception of Estonia, Lithuania, Italy and Slovakia. Most of the countries above the EU27 weighted average are also growing faster, with the exception of the Netherlands, UK and France (and, in an international comparison, the US).

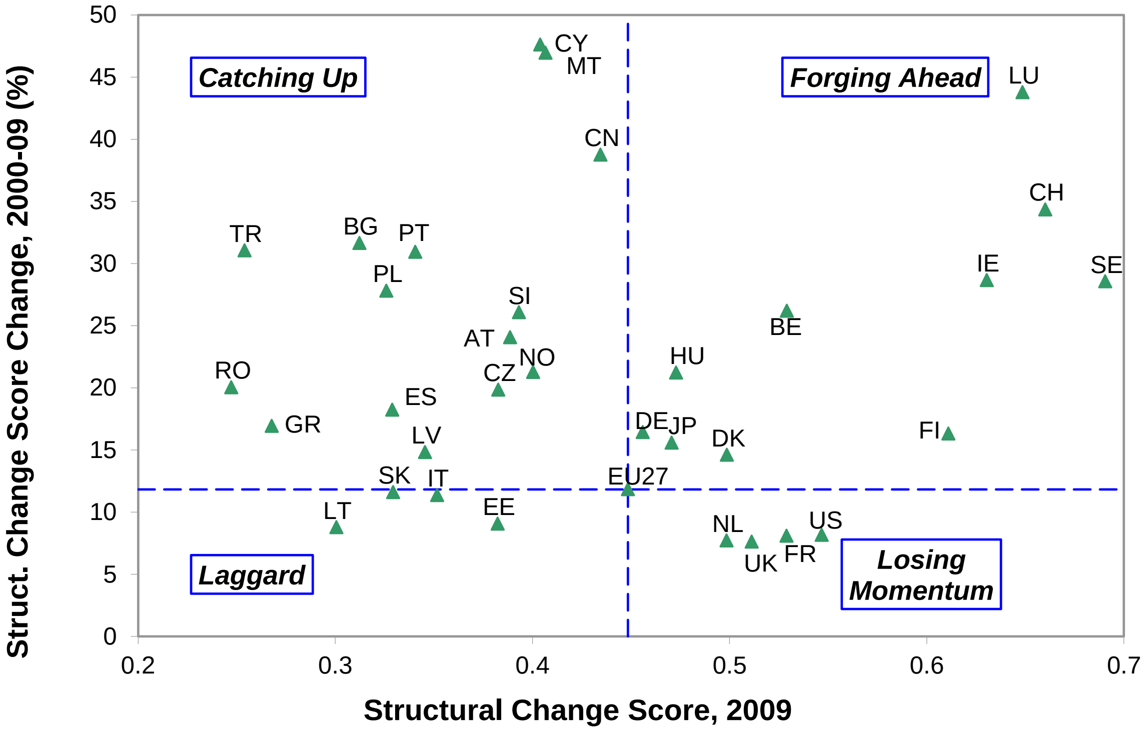


Figure 5 Composite Scores 2009 vs. Score changes 2000-2009, (geometric average aggregation method)

Figure 6 is based on the geometric average aggregation method. If the arithmetic average is used, the result is more polarized, with Cyprus, Luxemburg, China and Malta emerging as leaders, all having achieved a 50% increase in 2009 compared to 2000 levels, while the other countries ranging between 5-30% increase.

Based on the level of change in the composite indicator, the countries can be divided into three groups characterized by slow, moderate and fast increase of their score over the period 2000-2009 (Figure 6). Quartiles were used as cut-off points for identifying classes in the geometric-average-based data composite score change values.[11] The country lists are also summarised in Table 6, using both methods of aggregation.

[11] Q1, Q2, Q3 divide the countries' growth data set into four equal groups; the Q1-Q3 inter-quartile range identifies the middle ranks countries (half of the countries). We called this as the "moderate increase" group.

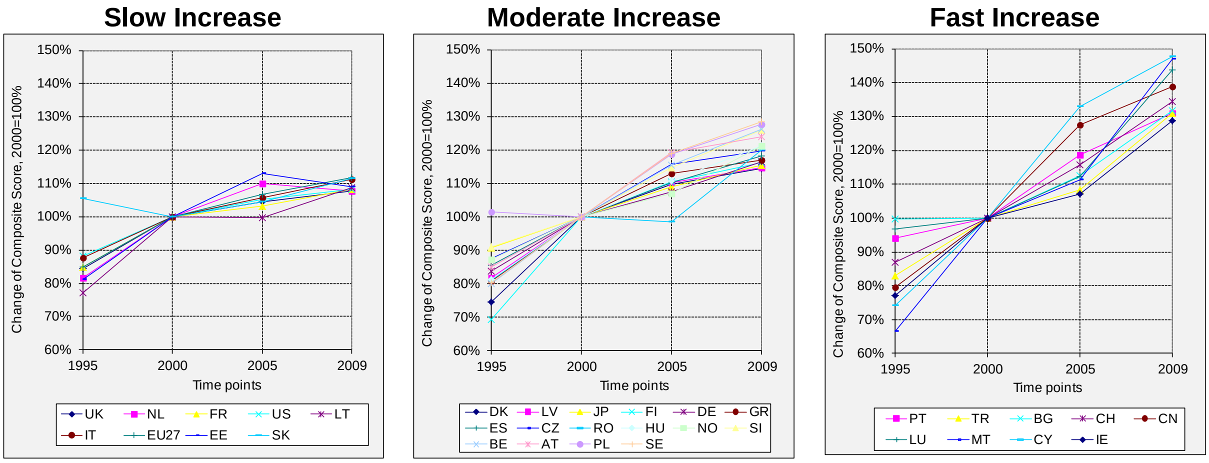


Figure 6 Change of composite index levels by quartiles (1995-2009, 2000=100), using geometric average aggregation

Table 6 Country groups by relative level change in composite scores (2000-2009)

	Arithmetic Average method	**Geometric Average method**
Fast Increase (First Quartile)	CN, LU, CY, MT, CH, BG, PT, BE, TR	CY, MT, LU, CN, CH, BG, TR, PT, IE
Moderate Increase (Interquartile range)	PL, SE, SI, RO, AT, CZ, LV, GR, IE, ES, FI, HU, NO, DE, JP, DK	SE, PL, BE, SI, AT, NO, HU, RO, CZ, ES, GR, DE, FI, JP, LV, DK
Slow Increase (Fourth quartile)	IT, SK, EU27, US, FR, NL, UK, EE, LT	EU27, SK, IT, EE, LT, US, FR, NL, UK

Based on Figure 6

Countries in the first quartile (Fast increase group) have achieved at least 29% (Ireland) increase over the period 2000 to 2009, ranging up to 48% (Cyprus). This is a very heterogeneous group, which consists of both the smallest countries of Europe, but also large countries with less developed economies (i.e. China, Turkey). Switzerland is an odd-one-out: while most of the countries in this group achieved high growth in the composite level because of their relatively backward ranking in 2000, Switzerland was in the top 5 already in 2000. The map in Figure 7 provides a more detailed overview of the level changes with its 5-step scale. It is interesting to see that neither location, nor the geographical or economic size, sets apart countries in terms of structural change over time.

Those countries showing slow increase also include larger economies, such as the UK, France, Italy or the EU27 as a whole and the United States, but also smaller ones such as Lithuania, Estonia and Slovakia.

Looking at composite levels as well as change over time simultaneously (i.e. maps in Figure 4 and Figure 7) allows the identification of countries with structural problems in their economy. Italy, Slovakia and Lithuania are in this way flagged as having relatively low structural change composite scores in combination with a low ratio of change over time.

In an international comparison, China clearly stands out by demonstrating the highest ratio of change (39%) from time point 2000 to time point 2009. Japan achieved a more moderate 16% increase, compared to the 12% of the EU-27 and the mere 8% of the US. Such a trend is what one would expect based on convergence hypotheses and considering the 2000 levels. Yet it raises questions about the near future, when both Europe and Japan may very likely be overtaken by China, indicating that it would be more apt to perform high-tech, innovative activities.

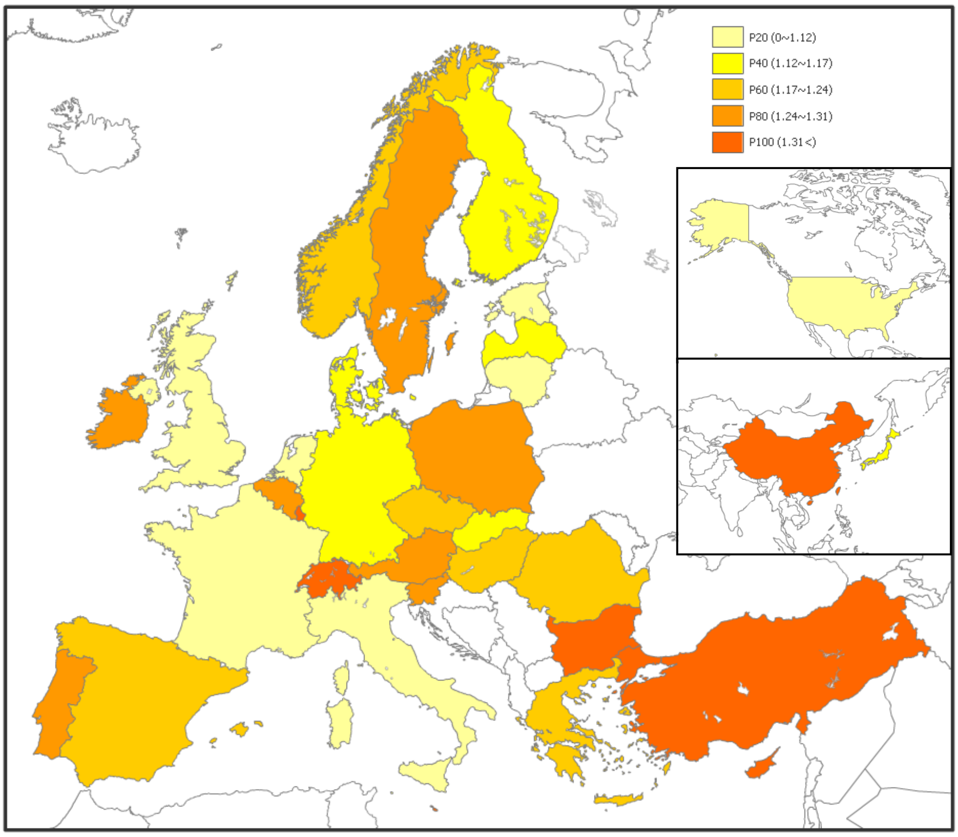


Figure 7 Map of structural change composite score changes, 2000-2009 (geometric average)

Copeland scores, a non-compensatory, multi-criteria ranking method

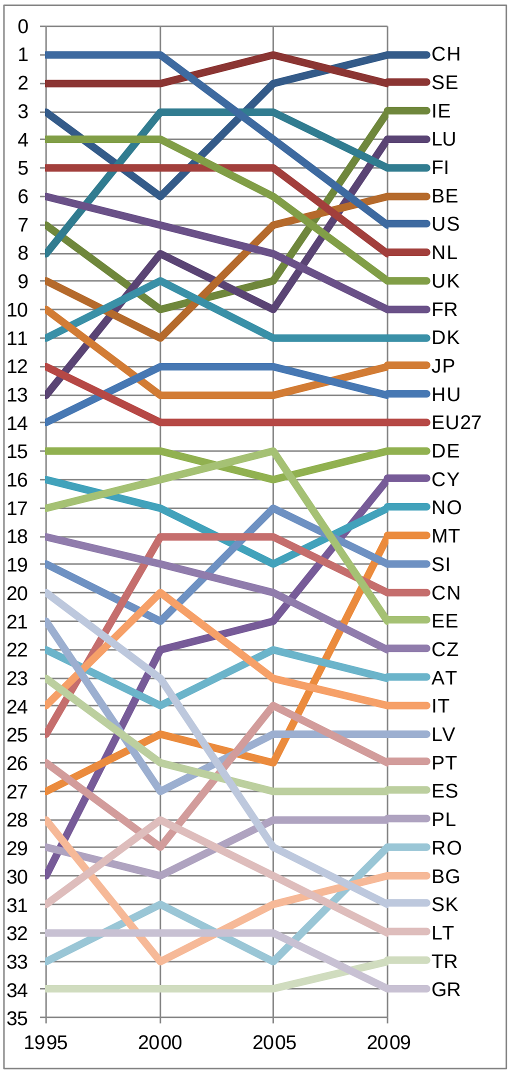


Figure 8 Country rank positions based on Copeland scores, 1995-2009

As an alternative to the geometric and arithmetic average methods of aggregation, composites can also be calculated using the non-compensatory 'Copeland scores'. This technique is primarily used when the various indicators carry different comparative information. Country scores are obtained by summing indicator-by-indicator country ranks into an outranking matrix, which is converted into a table of final ranks.[12]

Figure 8 shows the changing country rankings derived from Copeland scores. Compared to the geometric average ranking method, none of the countries kept its initial position, although only few of the countries increased or decreased their positions significantly.

At the global level, the order is the same as in the case of using the geometric average: the US leadership is clear, followed by Japan, EU-27 and China, all of them keeping this relative ranking.

In Europe, the ranks change a little, although the top 5 countries are the same as using the geometric average method: Switzerland, Sweden, Ireland, Luxemburg and Finland occupy the leading positions. They are followed by virtually the same group of mostly North and West European countries diverse in size: Belgium, the Netherlands, UK, France, Denmark and Hungary. There are interesting dynamics in these two groups: while Ireland and Luxemburg improved their positions, the US, the Netherlands, the UK and France fell behind.

The lower-mid-ranks also show vertical movements, while the low end remains relatively stable with the same countries Greece, Turkey, Lithuania, Bulgaria and Slovakia ending the list. In this group there are two interesting trajectories to highlight: the rapid growth of Cyprus and Malta, and the rapid drop of Slovakia.

The correlation between the Copeland-score based ranking and the geometric-average based ranking is very high (with a coefficient of 0.98), meaning that the order changes very little if the Copeland scores are used (the country which is ranked more favourably in this latter method is Romania).

[12] Al Sharrah, G., 2010, "Ranking Using the Copeland Score: A Comparison with the Hasse Diagram". *J. Chem. Inf. Model.* 50, pp.785-791; and OECD-JRC 2008, *ibid,* p.112)

Drivers of change

Table 7 and Figure 9 provide a more detailed picture of changes over the 2000-2009 period at the pillar level. In an international comparison, the EU-27 achieved the greatest increase in the *internationalization* pillar (28% level change over the period 2000-2009). The 14% and 18% change in the *skills* and *sectoral specialization* pillars (respectively) of the EU-27 were, however, less than that of its Asian competitors. Nevertheless, the worst performer at the pillar level was the US, with negative changes in the *R&D*, *international specialization* and *internationalization* pillars. China achieved high growth in all pillars, except for *internationalization.*

Within Europe, the best performers in *R&D* pillar were Estonia, Cyprus and Portugal, with Slovakia, Latvia, Luxemburg and France showing decline. Almost all countries except for Lithuania achieved growth in the *skills* pillar, with the best performers being Romania, Turkey and Poland. Considering *sectoral specialization*, Sweden, Luxemburg, Finland and Slovakia achieved over 60% increase, while Estonia, Romania, Lithuania and Cyprus saw 6% decline. Smaller countries achieved the largest growth in the *international specialization* pillar, including Malta, Cyprus and Slovenia, while a large number of larger countries have seen decline in this dimension over 2000-2009. The *internationalization* pillar (FDI in and outflows) saw triple-digit growth for Luxemburg, Cyprus, Belgium and Ireland, and very modest growth (below 16%) for France, Greece and Denmark.

Table 7 Evolution of structural change pillars and composite scores (2000-2009)

	Composite (Geometric avg.)	R&D	Skills	Sectoral Spec.	International Spec.	Int'lization
AT	24%	6.7%	2.5%	-18.7%	2.8%	33.5%
BE	26%	5.0%	2.8%	-9.4%	8.9%	45.6%
BG	32%	22.3%	1.4%	-7.5%	19.1%	60.8%
CY	48%	10.8%	9.4%	-21.3%	-3.2%	82.3%
CZ	20%	0.9%	8.5%	-14.5%	2.9%	22.9%
DE	16%	10.8%	3.7%	13.6%	1.8%	12.4%
DK	15%	9.4%	2.5%	10.3%	-11.4%	13.6%
EE	9%	19.1%	0.0%	-12.9%	-30.9%	16.3%
GR	17%	5.3%	8.2%	-11.9%	6.9%	10.5%
ES	18%	15.2%	4.3%	-7.7%	3.6%	23.5%
FI	16%	5.0%	4.9%	18.5%	-14.8%	16.0%
FR	8%	0.0%	5.6%	-0.7%	14.9%	4.3%
HU	21%	10.1%	3.7%	6.0%	0.7%	28.5%
IE	29%	42.0%	10.9%	7.0%	-5.6%	56.7%
IT	11%	5.8%	4.5%	0.6%	1.4%	14.5%
LT	9%	9.1%	11.1%	-7.2%	22.2%	12.1%
LU	44%	3.4%	17.1%	41.8%	6.5%	88.1%
LV	15%	-28.6%	16.4%	15.6%	5.7%	20.9%
MT	47%	-1.7%	8.3%	39.9%	94.4%	38.2%
NL	8%	-2.6%	3.7%	-9.0%	-11.7%	11.5%
PL	28%	13.6%	14.7%	-15.5%	6.1%	23.3%
PT	31%	34.5%	7.5%	-1.3%	-7.0%	23.6%
RO	20%	3.6%	13.1%	6.2%	67.2%	28.2%
SE	29%	0.8%	1.2%	-0.3%	0.5%	44.2%
SI	26%	12.2%	7.3%	-10.6%	20.6%	22.8%

SK	12%	-11.7%	1.5%	42.1%	-4.4%	14.1%
UK	8%	4.6%	5.9%	-6.7%	-11.3%	26.0%
TR	31%	26.6%	19.2%	0.5%	46.0%	17.4%
CH	34%	4.0%	7.8%	9.2%	11.8%	55.0%
NO	21%	12.2%	5.1%	19.1%	5.1%	25.6%
EU27	12%	2.3%	5.1%	-0.1%	-1.3%	19.1%
US	8%	5.0%	3.5%	12.6%	-6.9%	0.5%
JP	16%	2.0%	5.6%	9.6%	0.8%	12.9%
CN	39%	16.6%	9.8%	13.4%	6.8%	-1.2%

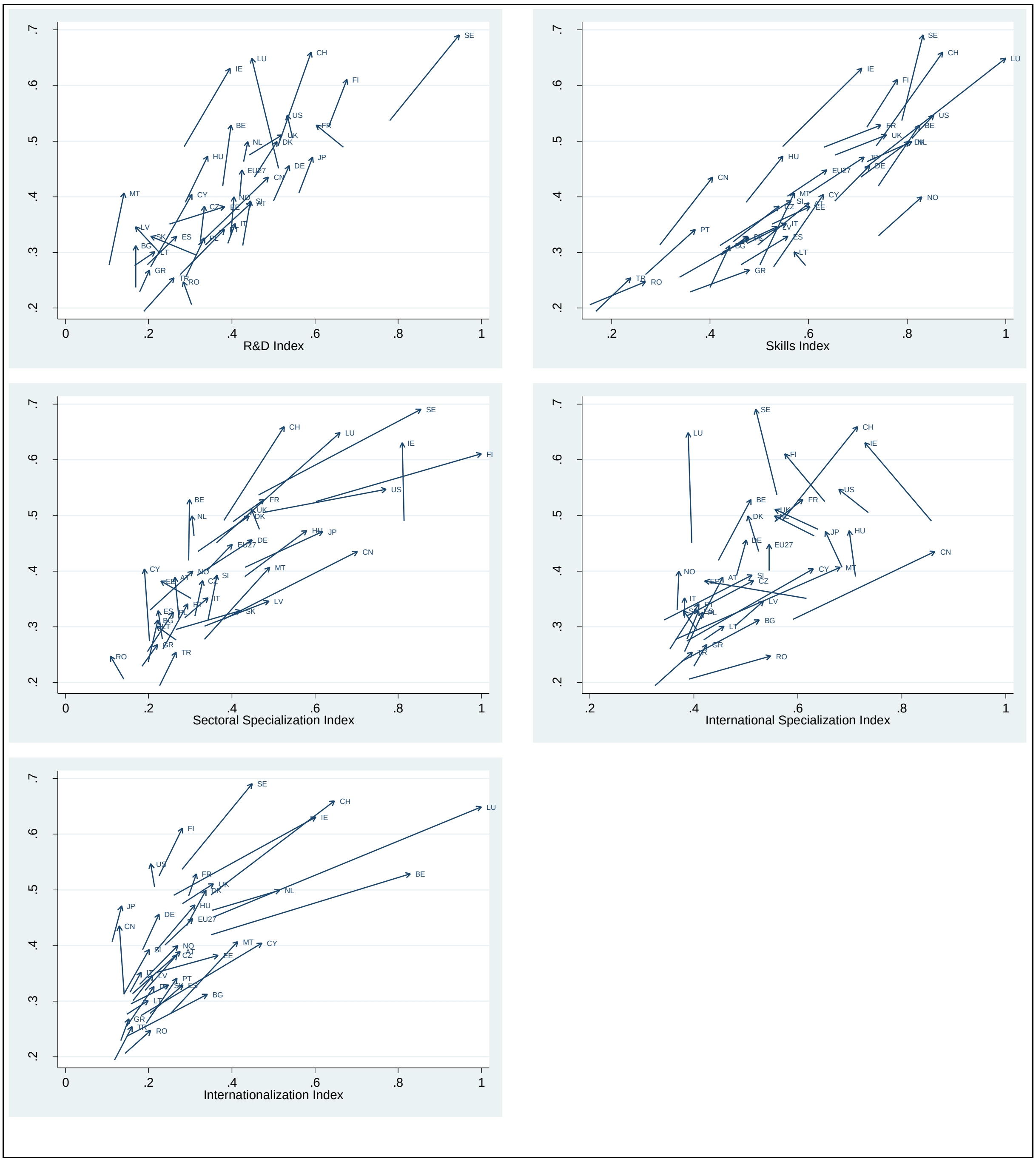


Figure 9 Change in structural change composite indicators against the 5 pillars over time (2000 to 2009, geometric average used)

Sensitivity analysis

We have carried out a global sensitivity analysis[13] to appreciate the relative importance of the indicators for the overall composite in terms of the so-called first order sensitivity indices (S_i). The value of these indices may vary within the range [0.0 - 1.0] and indicate how important each indicator is in terms of driving variability on the overall composite indicator.

In our model we assumed that all indicators (and thus pillars) are of the same importance for the composite on structural change. The sensitivity analysis revealed on the one hand a lower effective contribution of R&D indicator C2 and technological specialization indicator C9 to the composite score at time point 2000, and of C2, C9 and inward FDI stock indicator C12A at time point 2009. This is not surprising, given the lower level of correlation of these indicators with the rest. On the other hand, no single indicator was excessively responsible for variance in the composite score. We also noticed that both the time point considered and the aggregation method affected the sensitivity scores (Figure 10).

Given the constraints of this study, no attempts were made to re-iterate the weights so as to converge towards a balanced importance of the indicators for the overall composite. Nevertheless, future studies may refer to the method suggested by Paruolo *et al*.[14] If a real equal weighting is desired for the composite indicator, one should consider giving higher weights to indicators with lower S_i values.

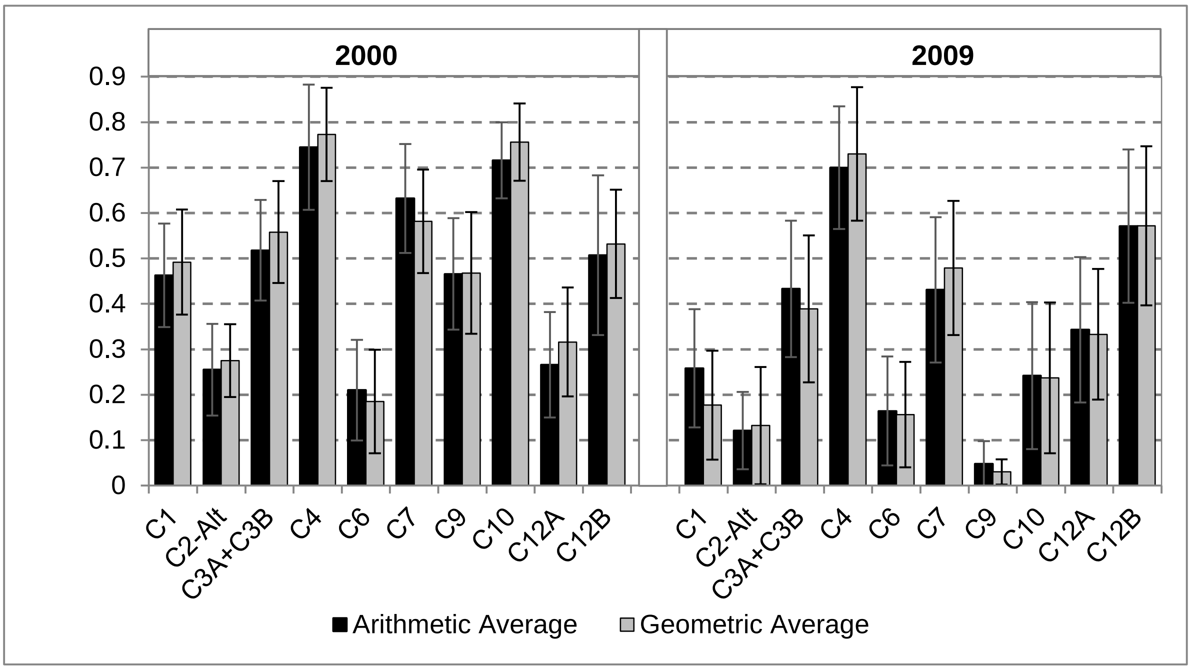


Figure 10 Results of the global sensitivity analysis of the composite against its indicators (years 2000 and 2009, arithmetic and geometric average aggregation method)

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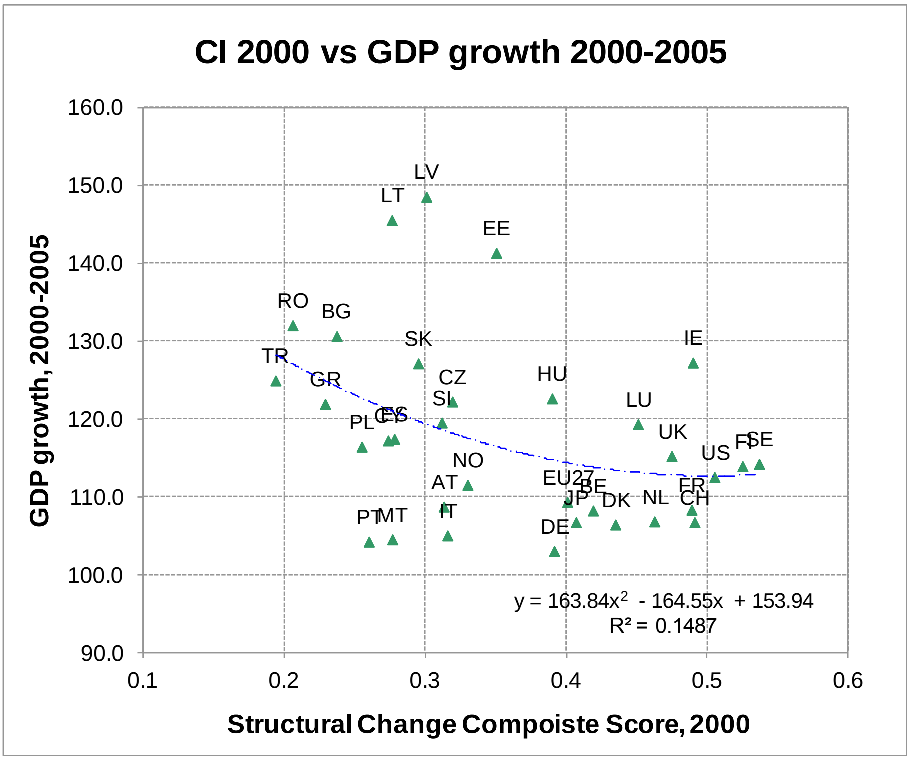
[13] The sensitivity indices of the first order $S_i=V[E(Y|X_i)]/V(Y)$ were computed from the $E(Y|X_i)$ curve, obtained by kernel regression of the original data points after Gasser *et al*., (1991). S_i has been computed by weighted averaging of the regression curve. Instead of a single estimate based on the 34 points available we have boot-strapped the points for the computation of $E(Y|X_i)$ using as many replicas as the sample size (34) and computed S_i mean and standard deviation. The resulting average S_i can be taken as a robust measure of importance.

[14] Paruolo, P., A. Saltelli and M. Saisana, 2011, "Ratings and rankings: Voodoo or Science?" http://arxiv.org/abs/1104.3009v1

__Outlook on the potential uses of the indicator__

The study tested the potential uses of the structural change composite indicators by looking at correlations with key economic indicators, such as changes in GDP, multi-factor productivity or unemployment levels. The initial results show that it requires a deeper study of the economies, of lag structure, to explore how the composite relates to other, more narrowly defined economic indicators. In other words, no significant correlations were found between levels or changes of the composite indicator and any of the variables mentioned above. For instance, the graph below plots the structural change composite score of 2000 against GDP growth over the subsequent 5-year period. There appear to be two clusters: one of countries with higher growth achieved with a less-developed knowledge-intensive, high-tech economic structure, and another one with high composite scores, but more moderate GDP growth. Yet out of this second group there may be a more positive relationship between structural change and growth -- but as the data shows, there is no strong U-shaped relationship.



7. Conclusions

This report is the deliverable of the second work package of the feasibility study entitled: 'ERA monitoring: composite indicators measuring structural change, to monitor the progress towards a more knowledge-intensive economy in Europe', financed by DG RTD.

For this deliverable we developed a composite indicator to measure structural change towards a more knowledge-intensive economy. The conceptual framework used in this study built on the findings and indicators list proposed by the Expert Group on the measurement of innovation in the report "Indicators for Structural Change" (Oct. 2011).

The Expert Group report divided potential structural change indicators into three groups: *enablers*, *compositional* and *Schumpeterian*. We found that, out of the latter two, only the *compositional* group consisted of indicators with sufficient data over sufficiently long time horizon to compute meaningful composite indicators.

The definition of the ten *compositional* indicators, grouped two-by-two into five pillars, proposed by the Expert group had to be slightly modified due to insufficient available data. These changes primarily affected the *sectoral specialisation* pillar where the new Eurostat definition of knowledge intensive activities has broader sectoral coverage then the currently computable statistics based on high-tech manufacturing and knowledge intensive services. Other definition adjustments were made to increase data availability, but these were of minor significance. In the end, a dataset of 9 indicators for 34 countries and 4 time points (1995, 2000, 2005, 2009) were computed for the study.

The correlation structure of the selected indicators showed that all significant correlations were positive. This fact reassured us that all the indicators point in the same direction and allowed us to use them to measure structural change. Principal component analysis (PCA) was conducted over all indicators, yet no meaningful latent dimension could emerge from the dataset. As a consequence, the conceptual grouping of indicators suggested by the Expert Group was maintained to measure structural change.

Each of the five pillars was computed by taking the mean of the two indicators it consisted of, except for the *sectoral specialization* pillar which is made by one indicator only. Composite indicators were then calculated using two standard methods: taking the arithmetic and the geometric average across the pillars. The difference between the two methods was found to be marginal. Moreover, this study tested a non-compensatory multi-criteria ranking method, based on Copeland scores, which resulted essentially in the same country ranking as the other two methods.

The results for year 2009 show that the five European leaders are Sweden, Switzerland, Luxembourg, Ireland and Finland. With a distance, they are followed by a North Western European "belt" with Belgium, France, the United Kingdom, the Netherlands and Germany, joined by Hungary. On the other extreme, the group with the lowest composite score includes Eastern (Romania, Lithuania, Bulgaria, Poland and Slovakia) and Southern Member States (Greece, Spain), as well as Turkey. The common feature of the best performing countries is their high scores in the *skills* pillar; the other pillars showing strong performance vary. Sweden's outstanding composite score is due to its high *R&D*, *sectoral* *specialization*, and *skills* pillars scores. Switzerland stands out in *skills*, *International specialization* and *internationalization*; Luxemburg in the *skills*, *internationalization* and *sectoral specialization* pillars. Ireland's strength lies in the *sectoral*- and *international specialization* as well as in the *skills* pillars, with a relatively weak score in *R&D*. Finland excels in *sectoral specialization*, *skills* and *R&D*, but has a below average score in *internationalization*.

In a global comparison, the United States are in a clear leading position, followed neck and neck by Japan, the EU-27 and China. The US performs best in the *skills*, *sectoral*- and *international specialization* pillars, but has a below average score in *internationalization*. In the case of Japan, good scores are the *R&D, sectoral specialization* as well as *international specialization* pillars, but a very poor *internationalization* score pulls back the country to the middle ranks. Interestingly, this profile is also valid for China.

Composite indicators of structural change are more meaningful when level changes are considered over time. Such trends use year 2000 as a reference time point. All countries have made progress toward a high-tech, knowledge-intensive economy since 2000, but the pace of change varies between 8 (the United Kingdom) and 48% (Cyprus). The results of the most recent financial crisis are not yet visible as the economic structure is slow to change.

Based on the level of change in the composite indicator, the countries have been divided into three groups characterized by slow, moderate and fast increase of their score over the period 2000-2009. Countries in the group of fast increase have achieved at least 29% (Ireland) increase over the period 2000 to 2009, ranging up to 48% (Cyprus). This is a very heterogeneous group, which consists of both the smallest countries of Europe, but also large countries with less developed economies (i.e. China, Turkey). Switzerland is a particular case as it was in the top 5 already in year 2000. On the other hand, the countries showing slow increase also include larger economies, such as the UK, France, Italy or the EU27 as a whole and the United States, but also smaller ones such as Lithuania, Estonia and Slovakia. It is interesting to note that neither location, nor the geographical or economic size, sets apart countries in terms of structural change over time.

Looking simultaneously at composite levels as well as change over time allows the identification of countries with structural problems in their economy. Italy, Slovakia and Lithuania are in this way flagged as having relatively low structural change composite scores in combination with a low ratio of change over time.

In an international comparison, China clearly stands out by demonstrating the highest ratio of change (39%) from time point 2000 to time point 2009. Japan achieved a more moderate 16% increase, compared to the 12% of the EU-27 and the mere 8% of the US. Such a trend is what one would expect based on convergence hypotheses and considering the 2000 levels. Yet it raises questions about the near future, when both Europe and Japan may very likely be overtaken by China, indicating that it would be more apt to perform high-tech, innovative activities.

The feasibility study also tested the potential uses of the structural change composite indicators finding no significant correlations with key economic indicators. Only a weak positive relationship between structural change and GDP growth was found for a sub group of countries with moderate GDP growth.

The results obtained with this feasibility study for the *compositional* group support the conceptual framework proposed in the Expert Group report. Therefore, we recommend employing the indicators of the *compositional* group, with the modifications made, for the measurement of this particular aspect of structural change. We also consider that, when data for the *Schumpeterian* indicators will become available, their different intrinsic substance and their different time-horizon should not induce us to aggregate them with those of the *compositional* pillar but to maintain the two groups well distinct. It will be the job of a follow-up study to populate the Schumpeterian group with the indicators specified in the Expert Group report.

Acknowledgements

The authors would like to thank their colleagues Michela Nardo, Michaela Saisana, Andrea Saltelli and Johan Stierna for their comments to preliminary versions of the report. In particular, we acknowledge Andrea Saltelli for his help in executing the sensitivity analysis for the overall composite and the single dimensions.

Comments from the experts

Rémi Barré

Professor of Science Policy, CNAM, France

The Report addresses the issue of the move towards a knowledge intensive economy through the assessment of 'compositional' structural change defined in terms of five pillars: RD, skills, sectoral specialization, technological specialisation and foreign direct investment. This way to address the central - yet complex - notion of a knowledge economy as a policy objective is welcome indeed on conceptual grounds. But the report demonstrates this approach - beyond its conceptual validity - allows for a complete and systematic measurement through 9 indicators (referring to five pillars), for 34 countries and 4 time points.

With respect to the indicators building and computation, the report is methodologically sound and solidly grounded: data sources identification and assessment, imputation of missing data, sensitivity analysis...

Finally a thorough quantitative analysis of the dynamics of structural change is presented, which is a very valuable and original achievement.

A few aspects deserve comments and suggestions:

- While understanding the necessity of having each country as such in the analysis, having Malta, Cyprus and Luxemburg in the same cluster (p 28) is a bit awkward (each representing about 0,01 % of the population of China); beyond that, indicators of change are not quite stable for very small countries, which calls for prudence in interpretation;
- No meaningful latent dimension could emerge from the data set through the principal component analysis (PCA), leading to build the composite indicator directly out of the five pillars. Box 2 shows that the first component gathers 46 % of total inertia, the second 16 % and the third 13 % (in all 74 %). From there further analysis could be done to see if an interpretation could be given for the components;
- The structural change indicators are not significantly correlated with key economic indicators (p.36); as suggested by the authors this requires a deeper study of the economies.

Matthieu Delescluse

DG-RTD, European Commission

With regards to indicators C10 and C10-alt, there is a definition of medium-tech products (not only high-tech) used in the Innovation Union Scoreboard.

The High Level Panel on Measuring Innovation proposed in 2010 a more robust indicator than C10 or C10-alt which focus on exports exclusively, namely the contribution of (medium and) high-tech products to the trade balance, expressed as % of total trade. This contribution is defined as: (Xi-Mi) – (X-M)x(Xi+Mi)/(X+M). This indicator is used by the OECD and overcomes notably the problem of re-exports which is a major weakness of C10 and C10-alt. I suggest using the indicator on the contribution to trade balance instead of the proposed C10-alt.

While one can accept that all the chosen indicators are all relevant to measure/study structural change, C5-alt is probably the core/headline one, as it measures the relative size of high-tech sectors in a given economy. The change in C5-alt in my view measures the essence of structural change in an economy.

The finding that this indicator has basically not changed for the EU between 2000 and 2009 (the change is even slightly negative, as shown in Table 7) should probably stand out more in the analysis. This means that high-tech sectors in the EU economy do not represent a larger share now than 10 years ago. This basically points to an absence of structural change towards more high-tech sectors in the EU. And actually, the growth rate of the indicator over 2000-2009 is negative for many EU Member States (Table 7), pointing to shrinking high-tech sectors with respect to the rest of the economy in these countries.

Also, the rate of growth of this indicator is not much more pronounced in China than in the US or even JP. Progress of high-tech sectors in the Chinese economy has not been much faster than in the US economy (Table 7).

The ranking on the composite indicator reminds of that of the Innovation Union Scoreboard. The correlation between the two, in 2000 and 2009, could be shown in the section devoted to the potential uses of the composite indicator. Of course, the overlap between the two composite indices in terms of indicators should be made clear, as well as the contributions of these common or highly correlated indicators between the two indices to the overall correlation between the two indices. Altogether, if the correlation between the two indices is not entirely due to overlap indicators' composition, this could yield some interesting observations on the link between innovation performance and structural change.

Emanuela Reale

Senior Researcher, CERIS, CNR, Italy

Well-structured work, clear in background and methodological choice; data analysis is accurate and conclusions on the topic.

Some remarks can be presented about a) the selection of alternative indicators with respect to those suggested from the ERA Expert Group, and b) the meaning of ‘structural change’ used in the data analysis.

As to the former, the choice of using GERD instead of GBAORD for C1(Alt) has the consequence of a different meaning of the indicator for structuring the R&D pillar (not the government budget on R&D but the whole expenditures for R&D). Is the alternative of using GOVERD not feasible?

A second remark can be outlined on the second indicator of the R&D pillar, namely C3(Alt). Using HRST instead of tertiary education attainment produce a very different meaning of the new indicator from the original C3A foreseen by the Expert Group. It is not clear to me why the OECD data on tertiary education attainment of population (or of population aged 25-64) were not used for all the countries since they have been computed for US, JP, CN and KR.

As to the meaning of structural change, the remarks on p. 25 about the equal weight attributed in the aggregation methods to the pillars, and the understanding of structural change as 'orientation toward specialization in knowledge based high tech sectors' must be more extensively commented as to the possibility to have misleading representation of the differences between countries.

Pierre Régibeau

Charles River Associates International and Imperial College London, UK

I would like to begin by saying that I was impressed by the clarity and professionalism of the report. I also agree with all of the significant methodological choices that the authors had to make. In particular, I believe that concentrating on the "compositional" aspect of structural change makes a lot of sense. "Enablers" are either policy instruments (if they can be directly controlled) or a description of the economic environment as shaped by these policies. To me, they do not at all capture the notion of economic structure. "Schumpeterian" indicators are not only hard to compute with the available data – as mentioned in the report – but, to my taste at least, they are too closely wedded to a particular view of how innovation "works".

Since I am not a data expert, I will not comment on the details of how the proposed indicators are actually calculated, leaving this to better qualified reviewers. I will therefore focus my attention on the broad question of whether the proposed composite indicator seems to adequately measure the type of "structural change" that is likely to be relevant to monitor progress towards the Europe 20/20 objectives.

My only major point of unease concerns the fifth "pillar" of the composite index. I simply fail to see how internationalisation is a relevant measure of an economy's structural change towards a more knowledge-intensive state. Why should a more knowledge-based economy be more "internationalised"? As an economist specialising in both industrial organisation (with emphasis on technology) and international trade, I just cannot see what rationale can be offered for such a link. More specifically, why would changes in the average of inward and outward DFI stocks be at all indicative of progress on the knowledge-intensive path? Is there any empirical evidence that DFI is more prevalent in knowledge intensive sectors of activities? I am not aware of any systematic empirical evidence pointing in this direction. If anything, on a conceptual basis, one would expect that knowledge-based expertise would be transferrable internationally through other means fairly easily. Firstly there are no reasons to believe that knowledge-based goods or services cannot be sold through exports as easily as other types of goods and services. Secondly, the presumption should be that international activities through licensing should be more prevalent for knowledge-based products or services than in other sectors. Overall, then, why would we expect the change in DFI to tell us anything about knowledge intensive activities?

On the other hand, there is ample evidence that the level of inward and outward DFI stock are influenced by a host of other factors such as discovery of natural resources, cost of manpower, local subsidies, tax laws and so on. So, even if the proposed indicators did tell us something about the knowledge –intensive structure of the economy, which I do not think it does, it would be an extremely noisy measure.

I now turn to a few smaller points:

- I understand that Brazil could not be included for data reasons, but what about South Korea?
- For data reasons, the composite indicator does not use C1, which relates to government R&D but C1(Alt), which relates to total R&D expenditures. I would suggest that there are reason to prefer C1(Alt) anyway. Again, government R&D expenditure is really a policy instrument. I usually think of economic structure as describing some aspect of the state of the economy. Some of these aspects can themselves be legitimate policy targets, while others are better seen as intermediate targets whose attainment facilitates the achievement of ultimate policy goals. In this perspective, Total R&D (or – maybe even better – private sector R&D) seems to fall in this second category much better than government R&D would.
- I have some reservations about C2. Consider two economies. One has a number of large firms that do their R&D in-house. The other has a rather different structure, where R&D is mostly outsourced to independent R&D companies. If I understand the definition of C2 correctly, for a given level of overall R&D investment, C2 would be significantly higher in the second country. Does this make sense? By extension, consider two countries that have experienced the same increase in overall R&D activities. However one country has kept doing R&D in the same manner as before (i.e. the mix between internal and external R&D has not changed), while the other has seen a move from internal to external R&D. Again, C2 would show more of an increase in the second country….but what does it tell us with respect to the two countries' R&D performance?
- Unless such an exercise will be conducted as part of a follow-up project (which would make some sense), the section on the potential use of the composite indicator is too short, in two respects. Firstly, I would have liked to see the relationship between the indicator and several potential measures of economic performance. Secondly, it would make sense to also show the relationship between each of the five pillars and the same measures of economic performance. This is because, eventually, one might think of weighting the different pillar based on their relative impact on the appropriate measures of economic success. Such an exercise is likely beyond the scope of WP2,

but a first look at how well each of the five pillars performs would be interesting and would provide food for thought.

Glossary

BRICS:	Brazil, Russia, India, China, South-Africa,
Candidate countries:	Croatia, Macedonia, Turkey,
EFTA:	European Free Trade Association composed of Switzerland, Iceland, Liechtenstein, Norway,
ERA countries:	Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Germany, Denmark, Estonia, Greece, Spain, Finland, France, Hungary, Ireland, Italy, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Poland, Portugal, Romania, Sweden, Slovenia, Slovakia, United Kingdom, Croatia, Macedonia, Turkey, Switzerland, Iceland, Liechtenstein, Norway, Israel,
ESTAT = Eurostat:	Statistical office of the European Union,
FYROM:	Former Yugoslav Republic Of Macedonia,
Grand Challenges:	Health, Energy, Environment (including Climate Change), Food, Agriculture, Fisheries,
OECD:	Organisation for Economic Co-operation and Development,
PCT:	Patent Cooperation Treaty
RCA:	Revealed Competitive Advantage
RTA:	Revealed Technological Advantage
UNESCO:	United Nations Educational, Scientific and Cultural Organization.

ANNEXES

ANNEX-I Construction of indicators C5-C7-Alt

As explained earlier in Box 1, the *high-tech manufacturing* and *high-tech knowledge-intensive services* definitions were applied to measure sectoral specialization. Although value added data based on these definitions were more widely available, neither Eurostat Structural Business Statistics (SBS), nor OECD Structural Analysis (STAN) databases were sufficiently complete to directly compute global aggregates, which was required for indicators C5-Alt toC7-Alt.

Sectoral specialization data were hence obtained by combining several datasets: EUKLEMS, OECD STAN, Eurostat SBS and national statistical publications. Given that the most authoritative source for growth and productivity measurement at the sectoral level is the EU KLEMS dataset; its March 2008 release covers 62 industries over a time span of 1970-2005,[15] this was used as the core dataset. Value added at constant 2000 prices was converted to USD dollars using OECD's purchasing power parities (PPPs) for GDP.[16] This core dataset was expanded in three steps: (1) where data permitted, physical production indices from OECD STAN or Eurostat SBS (in this order) were applied beyond the link year to extrapolate until 2008; (2) value added of countries with no EU KLEMS coverage, but with data from OECD STAN or Eurostat were aggregated from bottom up (i.e. in the case of BG, RO, CH or NO). In cases where data for some of the relevant sectors were missing for certain years, first sectoral data was computed by extrapolating the sector's shares in higher aggregates from known years. (3) In order to expand coverage, data from national statistical sources were applied for Turkey, Brazil, India and China. In the case of these latter BRIC countries, value added was used even if data on service sectors were incomplete, thus resulting in significant overestimation of the high-tech sectors.

Country notes:

- Austria (AT): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Belgium (BE): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Bulgaria (BG): Eurostat SBS data used (1999-2007)
- Cyprus (CY): EU KLEMS series used until 2005, updated with Eurostat SBS indices to 2008
- Czech Republic (CZ): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Germany (DE): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Denmark (DK): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Estonia (EE): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Greece (GR): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Spain (ES): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008

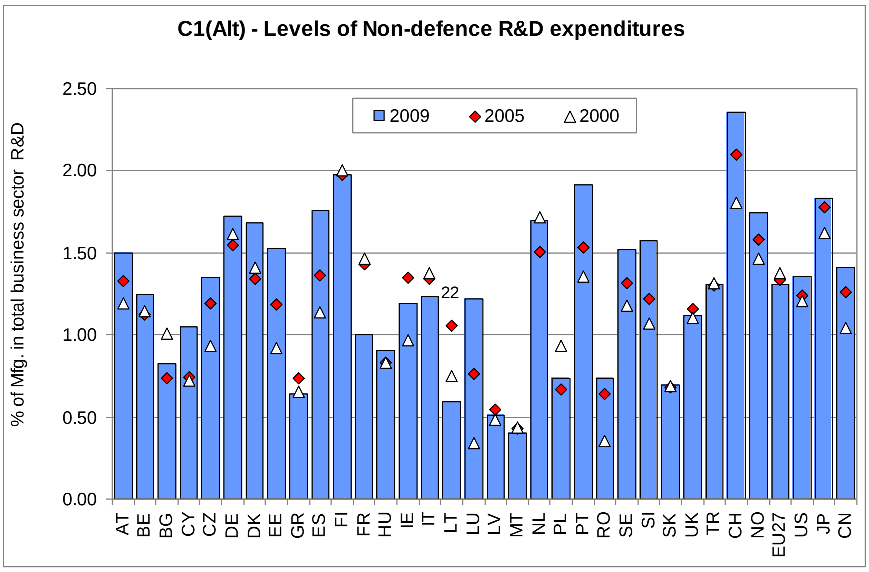
[15] see the citations to O'Mahoney and Timmer, 2009, *The Economic Journal,* Royal Economic Society, vol. 119(538), pp.F374-F403.

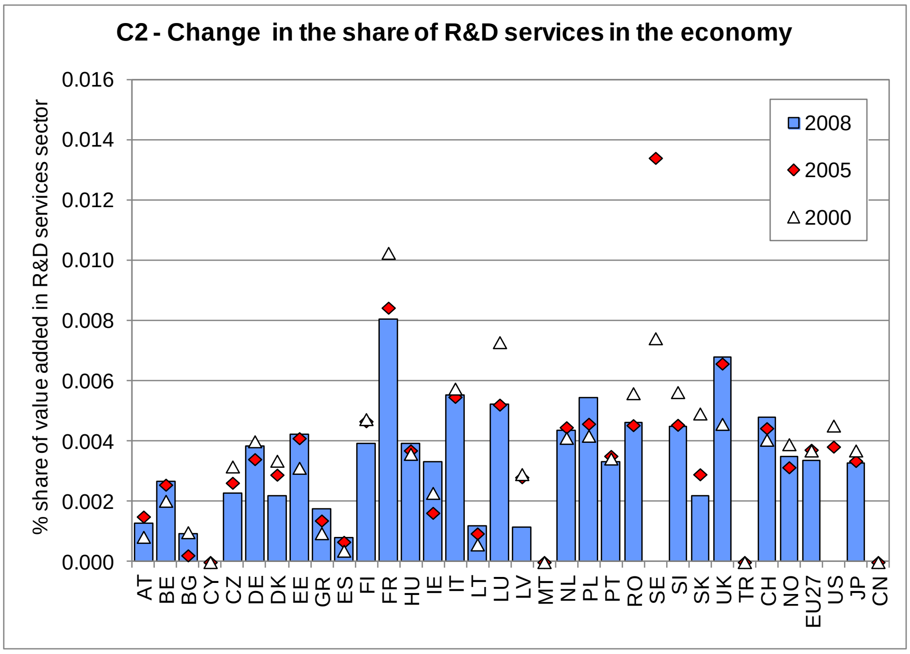
[16] Although not as precise as using industry-specific conversion ratios, PPP ratios for GDP were more broadly available for the combination of manufacturing and services sectors.

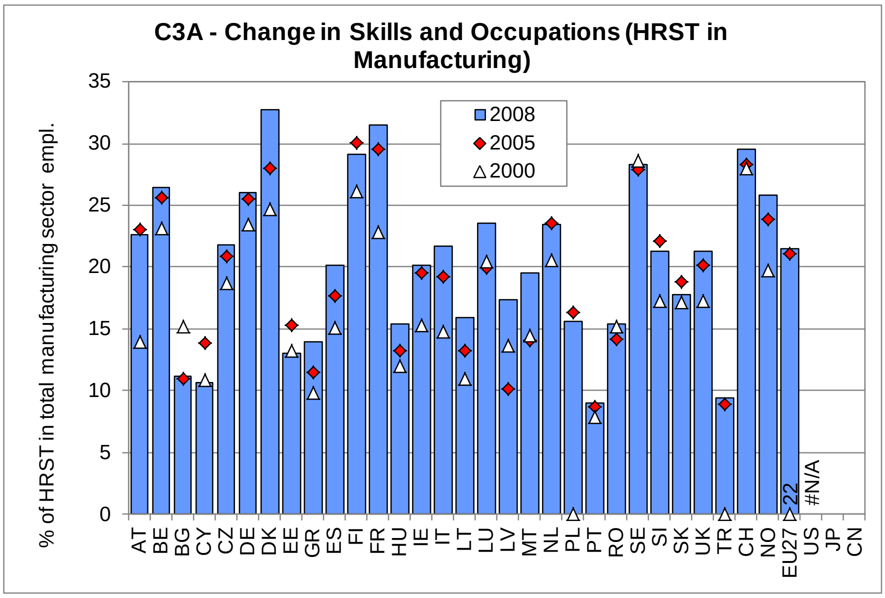
- Finland (FI): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- France (FR): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Hungary (HU): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Ireland (IE): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Italy (IT): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Lithuania (LT): EU KLEMS series used until 2005, updated with Eurostat SBS data to 2007
- Luxembourg (LU): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Latvia (LV): EU KLEMS series used until 2005, updated with Eurostat SBS data to 2007
- Malta (MT): no data on high-tech sectors
- Netherlands (NL): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Poland (PL): EU KLEMS series used until 2005, updated with Eurostat SBS data to 2007
- Portugal (PT): EU KLEMS series used until 2005, updated with Eurostat SBS data
- Romania (RO): Eurostat SBS data used (2000-2008)
- Sweden (SE): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Slovenia (SI): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Slovakia (SK): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- United Kingdom (UK): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Turkey (TR): TURKSTAT, Annual Industry and Service Statistics; value added at factor costs (YTL) [NACE Rev. 1.1 sectors 244, 30, 32, 33, 353, 64, 72, 73]; years 2003-2008
- Switzerland (CH): OECD STAN data used only (1997-2008)
- Norway (NO): OECD STAN data used (1995-2008)
- Brazil (BR): IBGE PIA data on value added for sectors 24.5, 30, 32, 33, 35.3 plus “Information and communications services” data used for years 1996-2008
- India (IN): Annual Survey of Industries (factory sector) data used (sectors 2423, 30, 32, 33, 353 – service sectors not surveyed); for years 1998-2008; World Bank PPP used for conversion
- China (CN): UNIDO value added data for selected industries (only available for manufacturing) available for 2003-2007 were extrapolated using output production index of Chinese National Bureau of Statistics for ‘hi tech industries’ to 1995, 2000 and 2008. Reference series for China is total manufacturing, not GDP.
- Rep. of Korea (KR): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008
- Japan (JP): EU KLEMS series used until 2005, updated with OECD STAN indices to 2007
- United States (US): EU KLEMS series used until 2005, updated with OECD STAN indices to 2008

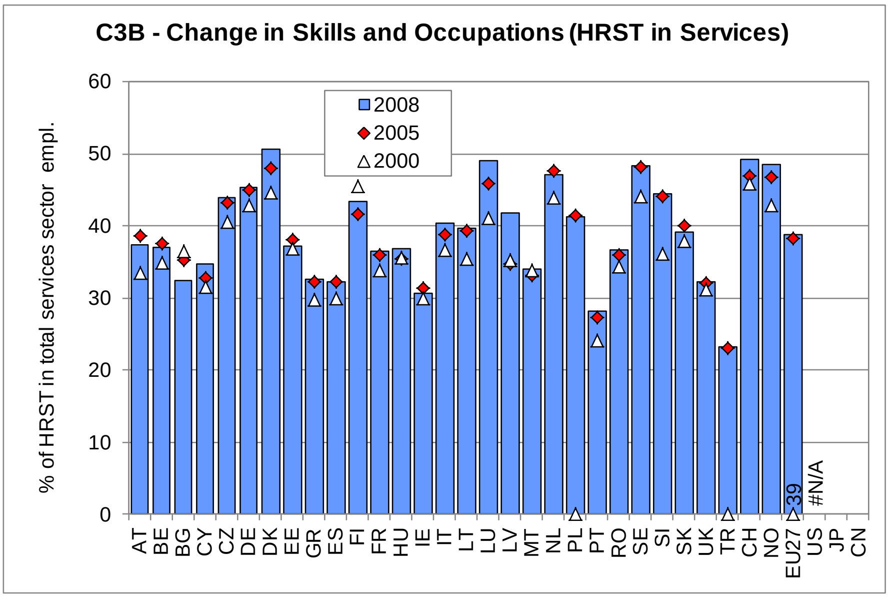
ANNEX-II Graphs of variables used for the composite indicators

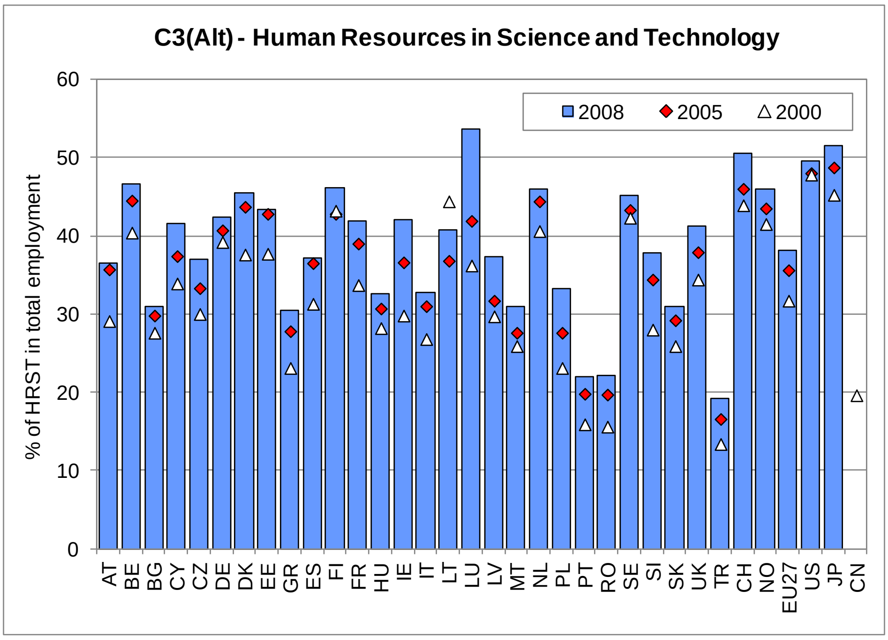
This annex presents graphs for the indicators of the compositional structural change. For detailed notes on sources and definitions, please refer to section 3.

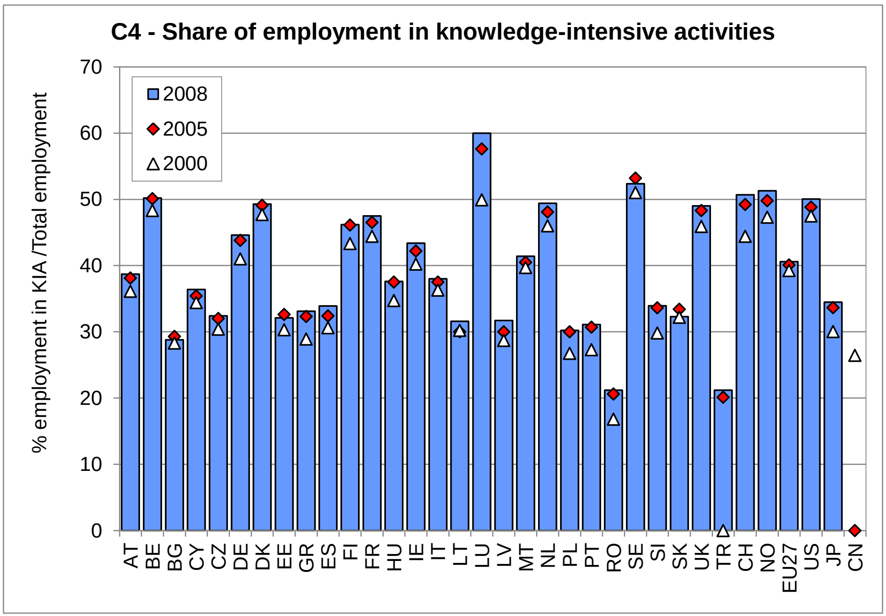


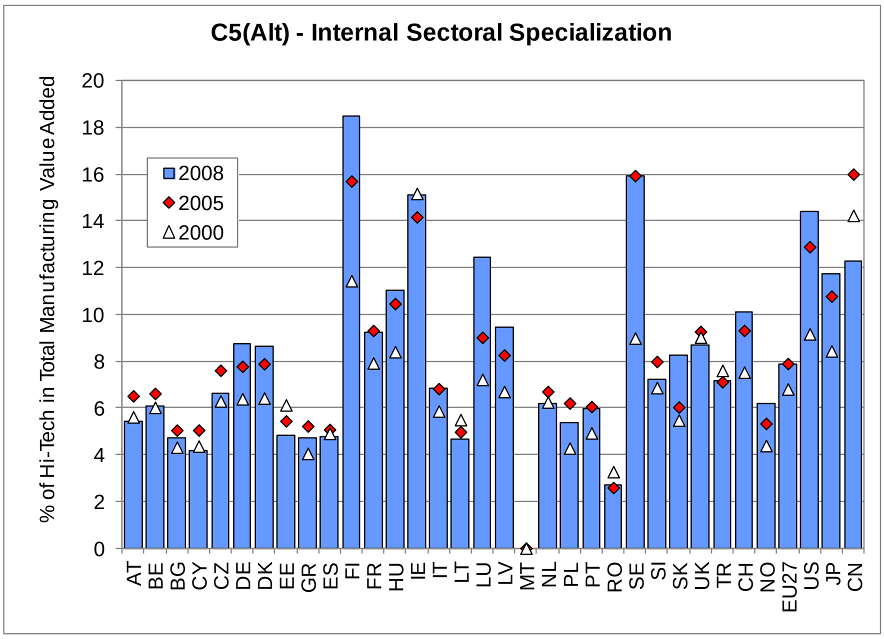


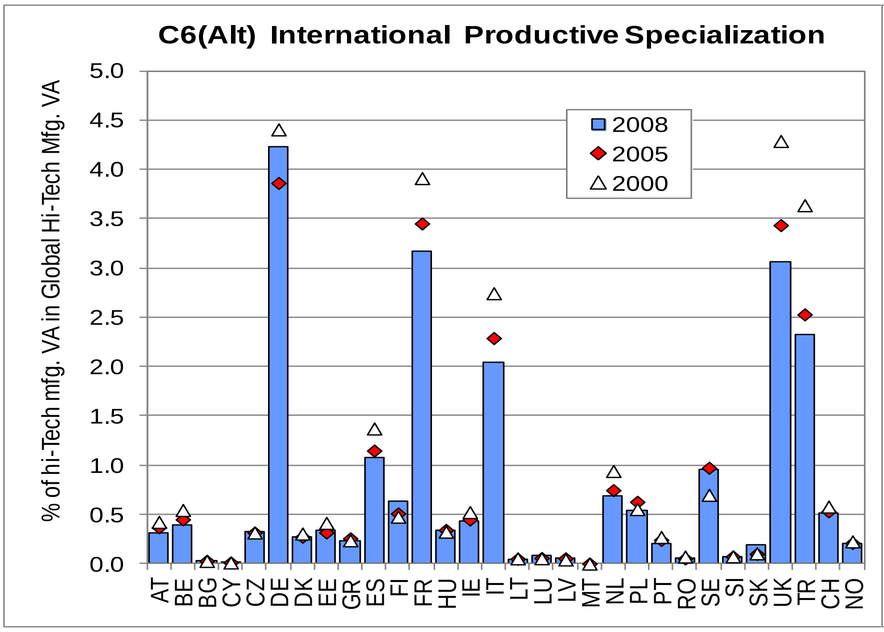

C3A - Change in Skills and Occupations (HRST in Manufacturing)
% of HRST in total manufacturing sector empl.
2008
2005
2000
22
#N/A
AT BE BG CY CZ DE DK EE GR ES FI FR HU IE IT LT LU LV MT NL PL PT RO SE SI SK UK TR CH NO EU27 US JP CN

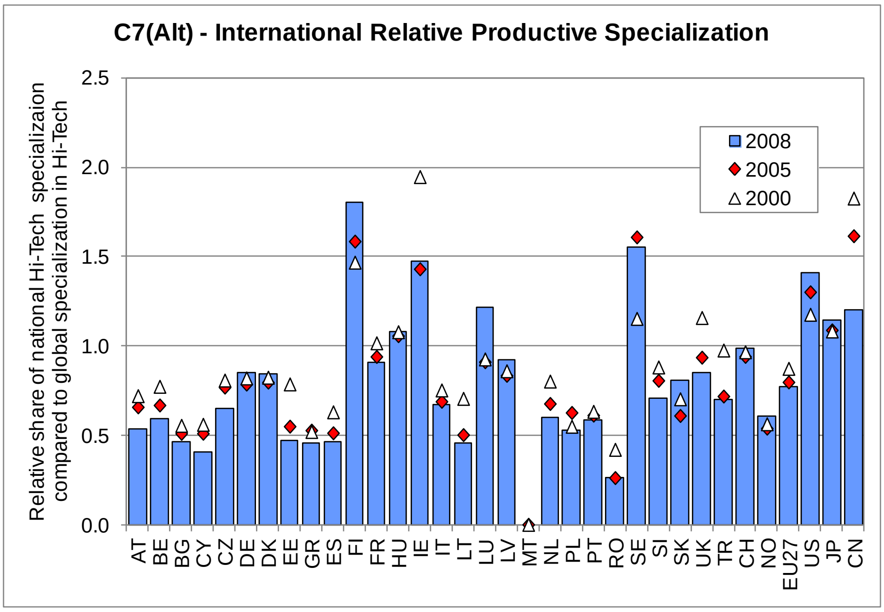

C3B - Change in Skills and Occupations (HRST in Services)
% of HRST in total services sector empl.
2008
2005
2000
39
#N/A
AT BE BG CY CZ DE DK EE GR ES FI FR HU IE IT LT LU LV MT NL PL PT RO SE SI SK UK TR CH NO EU27 US JP CN

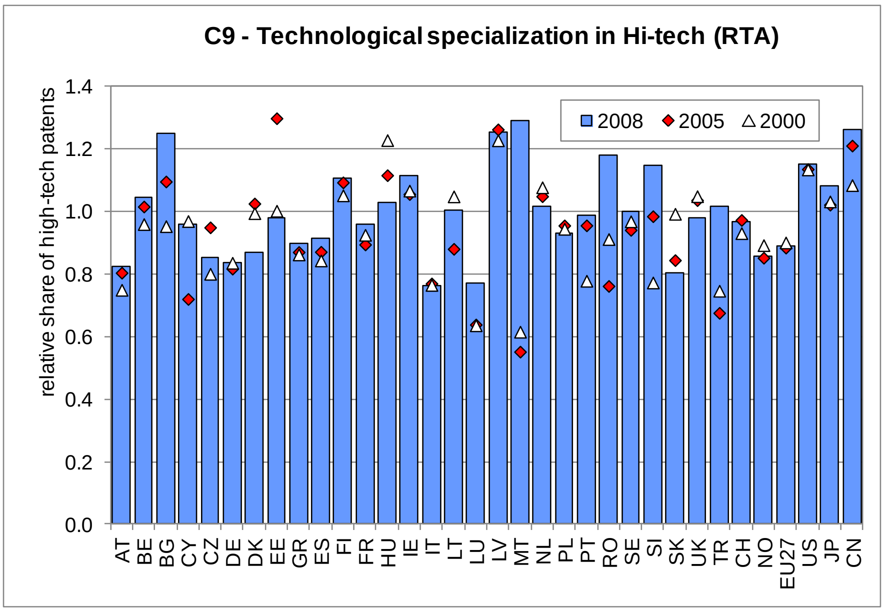

C3(Alt) - Human Resources in Science and Technology
% of HRST in total employment
2008
2005
2000
AT BE BG CY CZ DE DK EE GR ES FI FR HU IE IT LT LU LV MT NL PL PT RO SE SI SK UK TR CH NO EU27 US JP CN

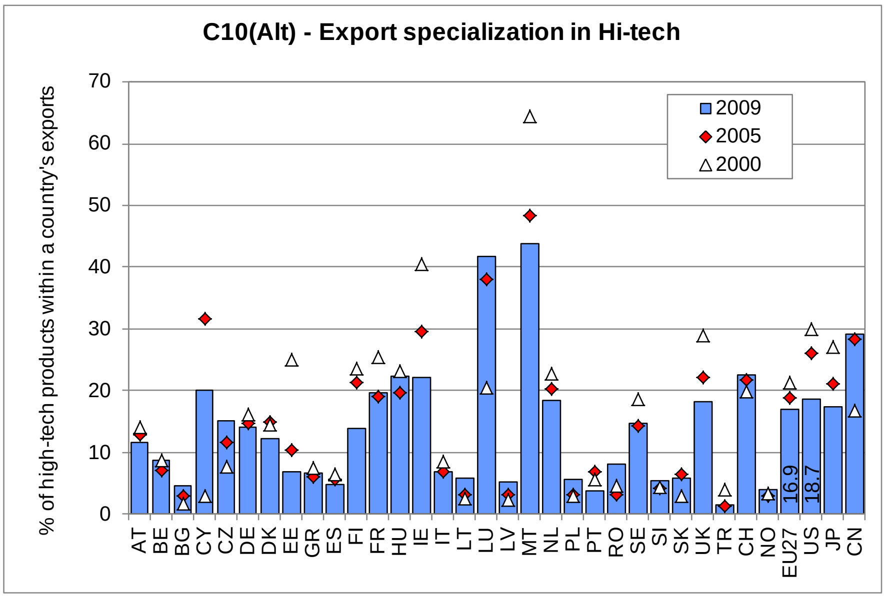

C4 - Share of employment in knowledge-intensive activities
% employment in KIA /Total employment
2008
2005
2000
70
60
50
40
30
20
10
0
AT BE BG CY CZ DE DK EE GR ES FI FR HU IE IT LT LU LV MT NL PL PT RO SE SI SK UK TR CH NO EU27 US JP CN

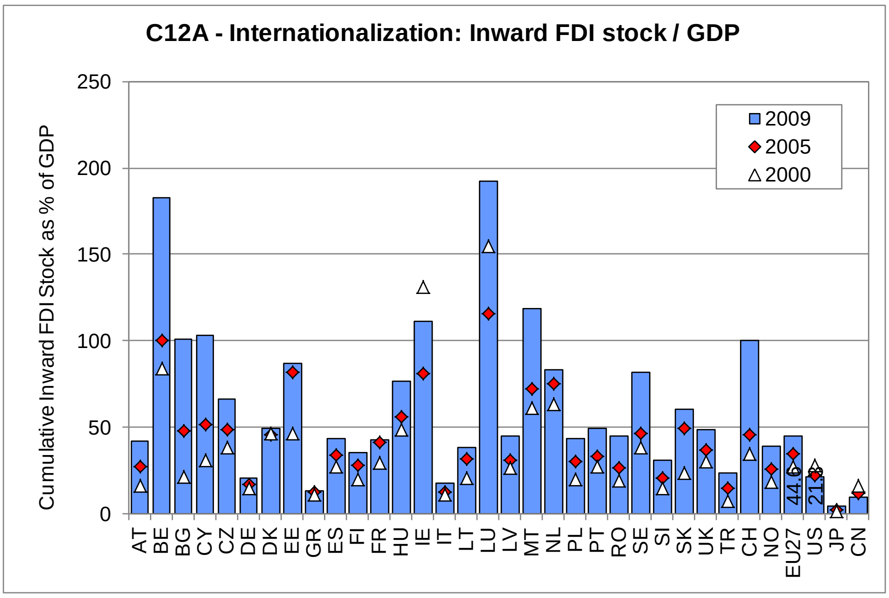

C5(Alt) - Internal Sectoral Specialization
% of Hi-Tech in Total Manufacturing Value Added
2008
2005
2000
20
18
16
14
12
10
8
6
4
2
0
AT BE BG CY CZ DE DK EE GR ES FI FR HU IE IT LT LU LV MT NL PL PT RO SE SI SK UK TR CH NO EU27 US JP CN

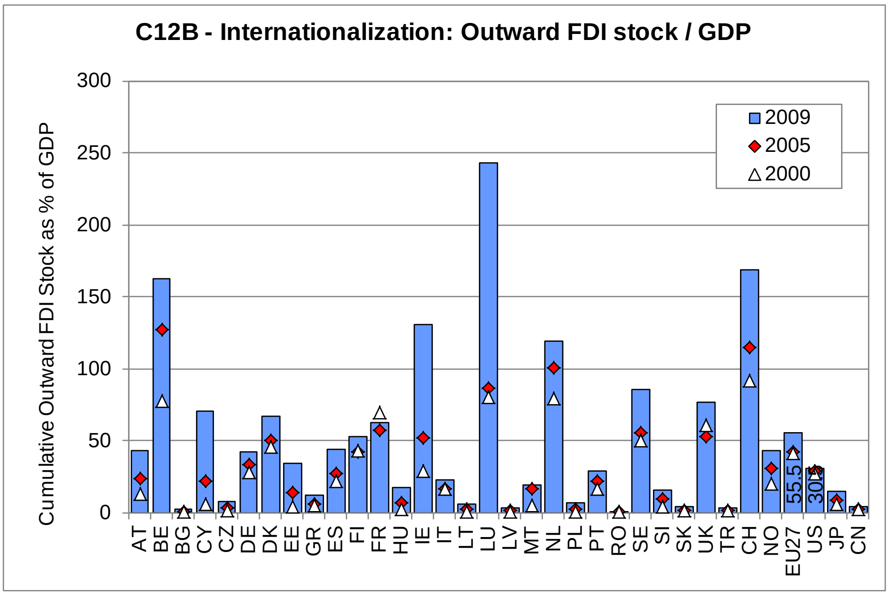

C6(Alt) International Productive Specialization
% of hi-Tech mfg. VA in Global Hi-Tech Mfg. VA
2008
2005
2000
AT BE BG CY CZ DE DK EE GR ES FI FR HU IE IT LT LU LV MT NL PL PT RO SE SI SK UK TR CH NO


C7(Alt) - International Relative Productive Specialization
Relative share of national Hi-Tech specializaion compared to global specialization in Hi-Tech
2008
2005
2000
AT BE BG CY CZ DE DK EE GR ES FI FR HU IE IT LT LU LV MT NL PL PT RO SE SI SK UK TR CH NO EU27 US JP CN


C9 - Technological specialization in Hi-tech (RTA)
relative share of high-tech patents
2008
2005
2000
AT BE BG CY CZ DE DK EE GR ES FI FR HU IE IT LT LU LV MT NL PL PT RO SE SI SK UK TR CH NO EU27 US JP CN


C10(Alt) - Export specialization in Hi-tech
% of high-tech products within a country's exports
2009
2005
2000
AT BE BG CY CZ DE DK EE GR ES FI FR HU IE IT LT LU LV MT NL PL PT RO SE SI SK UK TR CH NO EU27 US JP CN
16.9
18.7


C12A - Internationalization: Inward FDI stock / GDP
Cumulative Inward FDI Stock as % of GDP
2009
2005
2000
AT BE BG CY CZ DE DK EE GR ES FI FR HU IE IT LT LU LV MT NL PL PT RO SE SI SK UK TR CH NO EU27 US JP CN
44.6
21.8


C12B - Internationalization: Outward FDI stock / GDP
Cumulative Outward FDI Stock as % of GDP
2009
2005
2000
AT BE BG CY CZ DE DK EE GR ES FI FR HU IE IT LT LU LV MT NL PL PT RO SE SI SK UK TR CH NO EU27 US JP CN
55.5
30.4

ANNEX-III The comparison of high-tech and KiA classifications

	Old (technology-intensity based) definition		New (tertiary educated empl. based) definition	
Manufacturing			23[b]	Manufacture of coke, refined petroleum products and nuclear fuel
	24.4	Manufacture of pharmaceuticals, medicinal chemicals and botanical products;	24[b]	Manufacture of chemicals and chemical products
	30	Manufacture of office machinery and computers;	30[b]	Manufacture of office machinery and computers
	32	Manufacture of radio, television and communication equipment and apparatus	32[b]	Manufacture of radio, television and communication equipment and apparatus
	33	Manufacture of medical, precision and optical instruments, watches and clocks	33[b]	Manufacture of medical, precision and optical instruments, watches and clocks
	35.3	Manufacture of aircraft and spacecraft		
Services	61	Water transport		
	62	Air transport	62[b]	Air transport
	64[a]	Post and telecommunications		
	65	Financial intermediation	65[b]	Financial intermediation, except insurance and pension funding
	66		66[b]	Insurance and pension funding, except compulsory social security
	67		67[b]	Activities auxiliary to financial intermediation
	70	Real estate activities;		
	71	Renting of machinery and equipment without operator and of personal and household goods		
	72[a]	Computer and related activities	72[b]	Computer and related activities
	73[a]	Research and development	73[b]	Research and development
	74	Other business activities	74[b]	Other business activities
			75	Public administration and defence; compulsory social security
	80	Education	80	Education
	85	Health and social work	85	Health and social work
			91	Activities of membership organizations n.e.c.
	92	Recreational, cultural and sporting act.	92[b]	Recreational, cultural and sporting activities
			99	Extra-territorial organizations and bodies

Notes: a) Hi-tech KIS

b) KiA business industries (KIABI); shaded cells refer to high-tech aggregation.

c) based on NACE Rev.1.1

See Expert Group Report Table 1B p.13 for comparison according to NACE Rev. 2.

Source: Eurostat High-tech industry and knowledge-intensive services, Annexes 2 and 7 [URL: http://epp.eurostat.ec.europa.eu/cache/ITY_SDDS/en/htec_esms.htm]

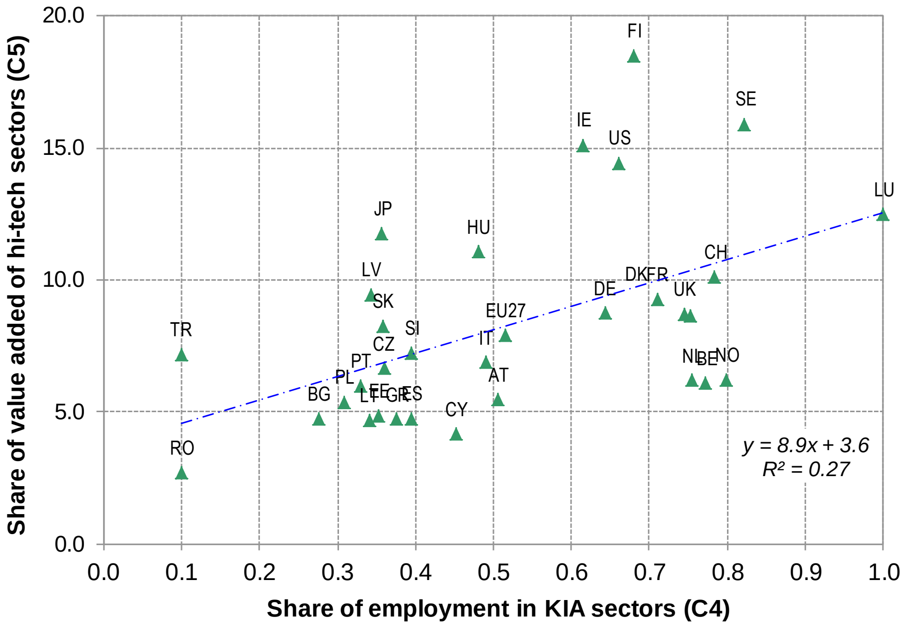


Figure 11 Comparison of the share of value added by hi-tech sectors vs. the share of employment in KIA sectors (2009)

European Commission

EUR 25279 EN – Joint Research Centre – Institute for the Protection and Security of the Citizen
Title: Composite Indicators measuring structural change, to monitor the progress towards a more knowledge-intensive economy in Europe
Author(s): Vertesy D., Albrecht D., Tarantola S.
Luxembourg: Publications Office of the European Union
2012 – 56 pp. – 21 x 29.7 cm
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ISBN 978-92-79-22546-8
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Abstract

This report is the deliverable of the second work package (WP2) of the feasibility study entitled ERA MONITORING and financed by DG RTD. The objective of this work package is to explore the possibility to develop a composite indicator of structural change towards a more knowledge-intensive economy in Europe, coherently with the orientations of the EU 2020 strategy and the Innovation Union initiative.

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